2012

Penn State AE Senior Thesis

The West Fuala Expansion

Abu Dhabi, PA

Final Thesis Report

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West Fuala Plant Expansion

Abu Dhabi, PA

Jaafar Al Aidaroos

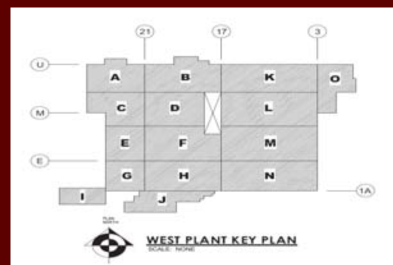
Construction Management

Web Address:

http://www.engr.psu.edu/ae/thesis/portfolios/2012/JMA5163/index.html

GENERAL BUILDING INFORMATION

Building name: West Plant expansion
Location: Abu Dhabi, PA
Building Occupant Name: Fuala Factory
Occupancy Type: S-1, F-1, B, A-2, A-3
Size: Existing – 208,237 SF, Addition – 350,545SF
Number of stories: 3 total, 1 basement and 2 above grade.
Construction Dates: Sept 2010 – March 2012
Deliver Method: Design-Build with Guaranteed Maximum Price
Cost: GMP = Withheld by Owner



ARCHITECTURE

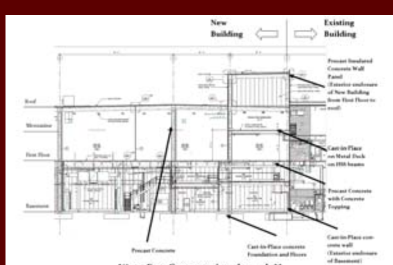
The New West Plant is a factory of three floors as follows:

Basement: production, storage and delivery.
First Floor : Offices, Storage, Manufacturing and Production.
Second Floor: Production, Office use and a Fitness center.

The floors are also separated into 15 sections, from A – J, each having a specific function in the new plant where areas K-O would be the old plant.

It is basically broken down into 3 sections; Left, center, right. Right is the old factory which currently running at 24 hours a day, 7 days a week.

The center and left part are the new west expansions and they are as follows: The First floor includes both center and left extensions; mezzanine would only include the center section; and the basement would include the lower part of both new sections which is ¼ the actual size.

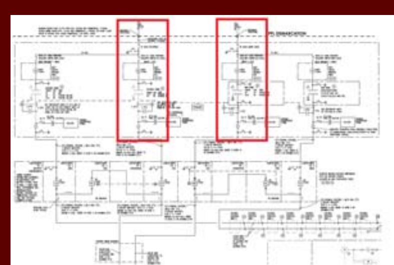


BUILDING STRUCTURE

- Basement Enclosure: Cast-in-Place S.O.G. & Exterior Walls.
- Basement Interior Walls: CMU Walls or Metal Panel.
- Basement Ceiling : Precast Concrete T-Beams as a roof with Cast-in-Place Concrete.
- First Floor : Precast exterior walls, Precast interior columns
- Roof: Precast T-Beams & EPDM with insulation.
- The Mezzanine: Metal deck on HSS beams connected to the Exterior Precast Walls.

MECHANICAL

- 32 VAV reheat units serving the entire west plant providing air at 180F.
- The reheat system ranges from 150 CFM up to 2400 CFM.
- The Cooling systems will be placed on the roof and will supply air at 42 F.
- There are 13 air handling units placed on the roof



ELECTRICAL / LIGHTING

- New Utility building: 69KV feeder along
- Old Utility building: 69KV feeder
- Total fed into Plant: 1200 Amps (600 from each)
- The 2 service entrances (Highlighted red box above) will be feeding 4 substations through distribution panels running a 3phase (4-wire) 277/480V circuit.
- In addition, each substation will have 2 backup generators running at 450KW – 562.5KVA.
- Main luminaire used: T8 florescent lighting all over.
- 2 back generators at each of the 4 substations that will activate upon loss of power.

2.0 Report Contents:

3.0 Executive summary:

The Final Thesis report contains the detailed information of the four proposed analyses for the West Fuala Plant Expansion. It is an addition of the original facility which is over a century old; the $83 Million expansion will cover an area of 324,403 SF. The building phase started on June 2010 and is planned to be completed February 2012. The purpose of these analyses will be to develop and research a more efficient and better design than the original along with studying new sustainable technologies; all these analyses will be conducted within four core requirements: Critical Issues Research, Value Engineering Analysis, Constructability, Review, and Schedule Reduction.

Analysis 1: BIM application – Incorporating Energy Analysis

BIM has been used throughout the project for clash detection and facilities management purposes. However, there many other benefits and uses of BIM that can greatly benefit the project process and the owner afterwards. For that reason, the proposed analysis will be determining the benefits of Energy Analysis and how it works.

Analysis 2: Feasibility of Incorporating Solar Photovoltaic Systems

Through energy calculations and process equipment requirements; The West plant’s energy consumption is expected to be extremely high. Since the process equipment are custom made where the electric feed/input that cannot be reduced; the only method to reduce energy usage would be to create another sustainable energy source; Hence, the photovoltaic panels. This will reduce the load and the electric usage from the grid. The goal is to be able to power at least one minor system completely and independently in addition to having an early payback period for the panels.

Analysis 3: Structural modification to a Precast Mezzanine

The majority of the West Expansion will be constructed from concrete with the exception of the steel Mezzanine. Having a project entirely from a specific material would be easier and faster to construct; on the other hand, having to build a project with many different types of materials and trades would not. For that reason, the second proposed analyses would be to change the Mezzanine from steel to precast concrete in order to be able to simplify the construction process and be able to save time and cost.

Analysis 4: Bathroom Prefabrication

According to the project team and project schedule, the bathroom/locker area has around 11 tasks that will take place within the same dates in the same area. The main task as requested by the project team was to prefabricate the piping system in the bathroom. This analysis will pursue this in addition to the possibility of attaining more advantages and benefits.

4.0 Acknowledgements:

Special thanks to all who supported and helped me throughout my Senior Thesis Project; my loving family, for their endless support during my life and my five year study at Penn State; my friends, for helping me throughout my studies and my life in the USA, and all the AE faculty and students for assisting me by providing moral and technical support at all times.

Scholarship Coordination Office:

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Dr. Robert Leicht	**Dr. John Messner**
James Faust	**Dr. Paul Bowers**

Turner Construction Company:

Holly Green	**John Rinaldo**
Shane Boyer	

Friends:

Mohamed Alali	**Abdulwahab Al Mousawi**
Hamad Al Rahmani	**Abdulla Al Hosani**
Ahmed Al Nachas	**Omar Al Dhaheri**

5.0 Project Background:

5.1 Introduction:

Building Name	The West Fuala Plant Expansion
Location	Abu Dhabi, PA
Owner	Private Entity (Confidential)
Purpose of Building	Industrial food production facility
Gross Facility Area	350,545 SF
Number of Stories	½ basement + Main Floor + Mezzanine
Construction Dates	Jun 2010 – Feb 2012
GMP contract	$83 Million
Project Delivery Method	Design-Bid-Build

Table 5.1: Project Overview

The West Fuala plant expansion project is an expansion of the original 208,237 SF facility which is over a century years old. The expansion will cover an area of 324,403 SF and will be constructed on the western wall of the original facility. The Eastern side will be attached to the old facility where there will be an open area between the two structures. The old structure would eventually become an office building while the new facility will take the role of production of this plant.

The building phase started on the June 2010 and is planned to be completed on Feb 2012 where it will production will begin as soon as the building is completed. The building consists of a basement along the southern side of the building, a first floor plan with an area of 207,765 SF and a mezzanine within the enclosed building with an area of 40,286 SF.

The basement will have an overall cast-in-place concrete structure while the first floor would be an overall precast system. The mezzanine will be supported on the first floor's precast wall using steel HSS beams which would run along the western wall of the old facility and overlooking the first floor below from the western side.

The original facility is located on an open area relatively isolated from everything around it. There are no building surround it directly nor are there any traffic obstacles that the project team may face during construction. The city has similar weather conditions to the city of Harrisburg in which the winter could have adverse effects on construction.

A design-bid-build delivery method has been chosen as a result of many factors. However, the main issue with this system was that there was minimal interaction between the project team since the designers have independently designed the facility, after which it was out for bidding and then to be constructed by Turner.

BIM has been used in this project for its most basic uses which is 3D coordination of the MEP systems, specifically clash detection. Biweekly meeting were conducted between the BIM coordinator and the team. BIM was also used for facilities management purposes. The model would be able to show where there are clearance issues with the equipment. At the end of the project, the model would be turned over to the owner and the process engineers so that they can use it for facilities management purposes in addition to helping the owner coordinate their process equipment

The Structural envelope of the facility was designed to be a precast concrete system except for the basement which was constructed using cast-in-place concrete. The mezzanine of the facility was erected using Hollow Structural Steel. Steel was chosen mainly since the MEP penetration would have to be known earlier when procuring the precast members; but since that was not possible, the structure was redesigned to steel since it does not require prior knowledge of the MEP penetrations.

Figure 5.1 - Site Bird-Eye View

5.2 Client Information:

The Fuala Co.'s is one of the largest chocolate factories and distributers worldwide. It all started in 1894 when the first decision to start producing was made; production continued and expanded in 1900. Now Fuala is exports to over 90 countries with approximately 13,700 employees and net sales in excess of $4billion. The Fuala Company remains committed to the vision and values of the man who started it all so many years ago.

The new West Plant expansion gained approval from the township which would turn this century-old plant to a modern state of the art facility. The existing 105 year old plant will become office spaces while the new plant expansion will expand production to be one of the world's largest and more advanced chocolate-making facilities. This expansion would lead to major growth in the facility and in turn will lead to growth in the stock market as it is one of the biggest gainers in the S&P 500 Index.

Project cost and budget is an important factor in order to meet the owner's expectations. This project is self-funded by the Fuala Company as an investment to its ever-growing and productive facility. The project changed from what was intended to be a $53.7 million expansion to an $83 million project. With that being said, Fuala has been very satisfied with the work done by Turner as the General contractor even though there have been a lot of changes in the scope of work.

Safety is also a very important factor in the construction process of this project as it is in any construction project if not the most important factor; hence, a lot of efforts have been made to maintain this standard. In addition to that, quality is very critical since this west expansion is for the next 50 to 100 years in which everything has be as good as new in order for it to do its intended purpose; especially that this will be the new main plant where all the products will be processed and shipped nationwide and worldwide on a 24 hours a day, 7 days a week schedule. Which mean that there a very low opportunity for mistakes or faults as this will take place to be the one of the world's largest chocolate plants in the world.

The most sensitive factor that is specific to this project is isolation between systems that may cause allergic reactions; especially that plant is a major almond processor. And so, a lot of care and attention was given to the factor that there had to be solid isolation between the nuts processing section and the other sections. Rooms have been separated with sealed walls with no doors; the worker's bathrooms have been segregated between the two sections where workers would not even have the ability to go into the other section if they have been in the first. In addition, each section would have their own entrance, so much that the workers working in the facility may not meet or know the workers working in the other section in order to keep both sections running as clean and as isolated as possible. There are a lot of things that have been taken into consideration to maintain a clean and segregated environment such as have separate HVAC systems so that even particles may not be able to travel through the systems to the other side.

As for sequencing, there were several sequencing issues that contributed to the current approach on the project beyond meeting the Contractual Milestones. Firstly, the office building expansion includes upgrades / reconfiguration to the existing Locker rooms which are in constant use. This has required Turner to perform certain work during plant shutdowns and will require partial completion of the new locker spaces to allow workers to be shifted out while they retrofit the existing. In addition, maintaining operating plant access, employee entrances, roadways, and so on had to be taken into account in planning all of the site improvements to minimize the impacts to daily operation since the facility operates 24/7 except for planned shutdowns over Thanksgiving and Easter.

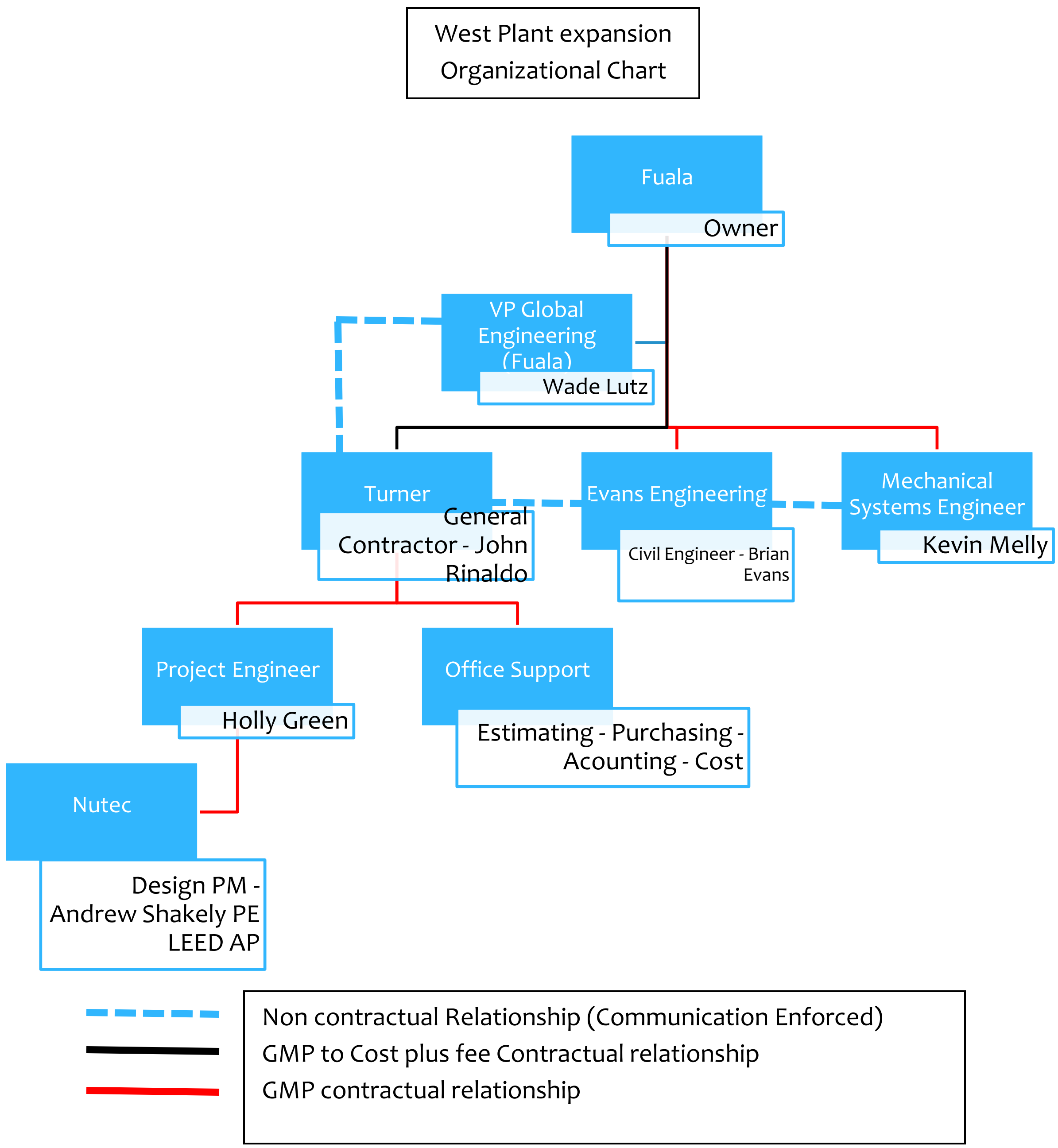
5.3 Project Delivery System

The Fuala Company chose a Design-Build approach from the beginning. Initially, Nutec Group took the lead as the Architect and Engineer of the project which is where the initial design was created. Evans Engineering is a relatively small local firm from the area that took the role of the civil engineer in addition to working with zoning regulation and the geotechnical issues. Nutec and Evans were there first of the project team were they worked on the design and initial paper work and permits. Later on Turner was chosen as the General Contractor that would take the project from paper and plans to construction and completion. They joined the team earlier and assisted in the pre-construction phase with architects and engineers in order to facilitate and be able to manage the project effectively and efficiently.

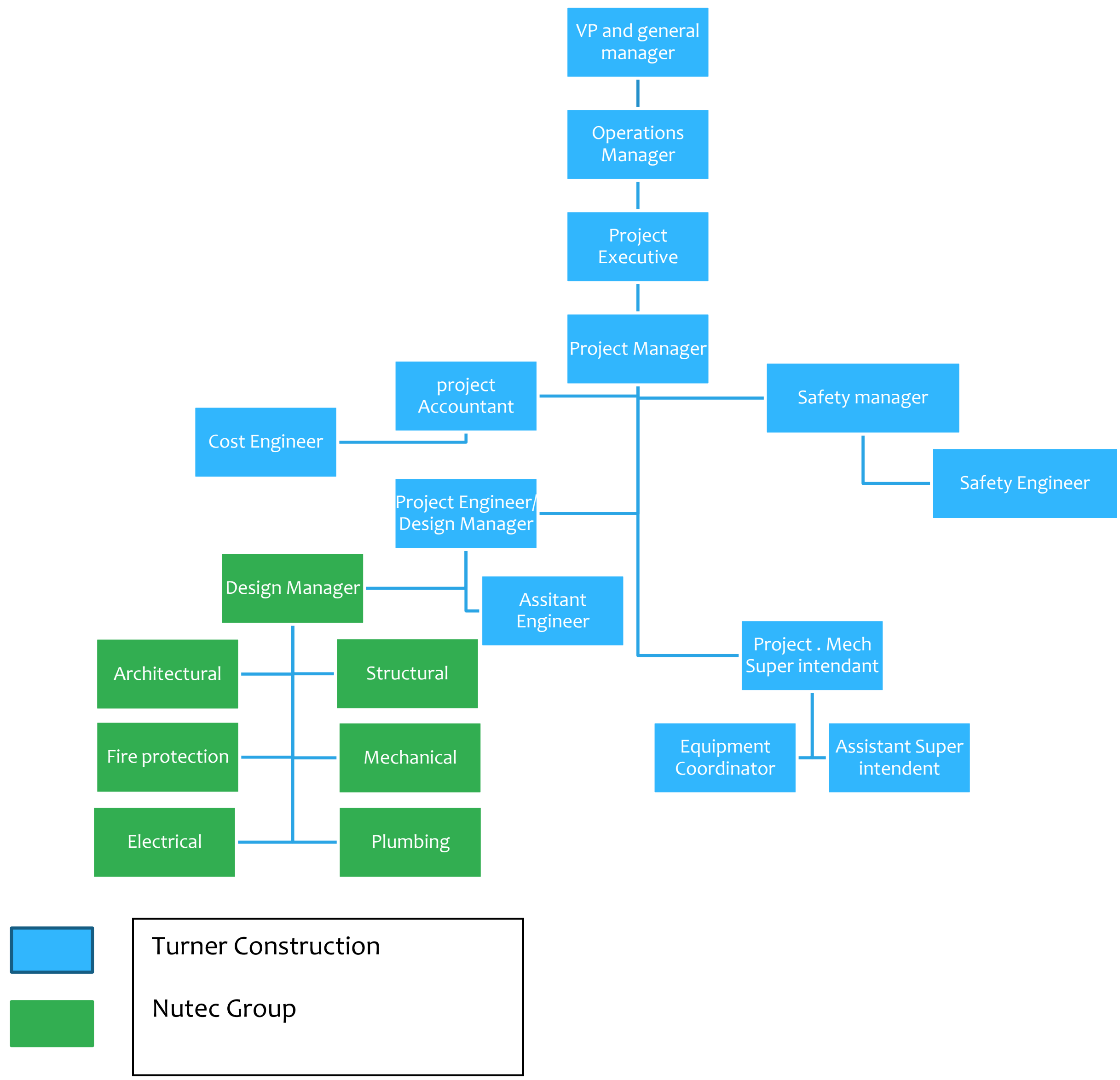
Even though the project team collaborates and works together in this project to complete the construction process as smoothly and as effectively as possible; they are all separate from each other with each having its own contract with the owner. The rest of the contractors are working through Turner and communicates and worked in the project under the wing of the General contractor as separate subcontractors.

As for the selection of Turner, selected Construction Management/General Contractors were invited to submit proposals then Fuala negotiated with a specific selected group and was awarded to Turner. With regard to the subcontracts with Turner, Turner created scopes of work which were provided to Turner and Fuala approved the contractors to bid. Upon the receipt of proposals, the low 3 to 4 contractors for each trade were brought in to review their scopes of work to assure all required work had been included. Subcontractors then submitted best and final offers based on the scope review meetings where the low bidder was awarded the project. The owner allowed Turner to provide Subguard on the project in lieu of bonds. Onsite insurance coverage for Turner and their contractors is provided by Turner's Contractor Controlled Insurance Program. The owner is providing the Builder's Risk Insurance Coverage with Turner providing an add on policy to coverage water infiltration loss.

The project was initially a Guaranteed Maximum Price (GPM) that later became a Cost plus fee as a result of the drastic change in scope that occurred as requested from the owner. The general contractor agreed to make any changes on the project to cater to the desire of the owner through the cost plus fee contract that was established.


West Plant expansion
Organizational Chart
Fuala
Owner
VP Global Engineering (Fuala)
Wade Lutz
Turner
General Contractor - John Rinaldo
Evans Engineering
Civil Engineer - Brian Evans
Mechanical Systems Engineer
Kevin Melly
Project Engineer
Holly Green
Office Support
Estimating - Purchasing - Acounting - Cost
Nutec
Design PM - Andrew Shakely PE LEED AP
Non contractual Relationship (Communication Enforced)
GMP to Cost plus fee Contractual relationship
GMP contractual relationship

5.5 Staffing Plan:



The staffing Plan is structured in a way so that everything goes through Turner Construction Company even though some have direct contracts with the Owner. The Staffing Plan above shows the relationship between the two major companies that are working on this project. Nutec group is the design team that includes all designers for the project. The Design team has to communicate with the Project engineer of Turner and reports to the same person. On the other hand, the Turner team is branched in a way that all communication goes through

The Project manager and operation Manager both report to the VP of Global Engineering (part of Fuala) which is main line of communication between the owner and the project team. All other contractors report to the owner directly however, Turner receives all updates as well as a result of this communication line. A meeting is held every Wednesday between the owner, Turner, Nutec group and Evans engineering. In addition, Turner meets as well with the inspection staff in order to ensure that the plant maintains a clean environment according to the drug and food administration requirements. These sets of meetings facilitate all problem solving issues and ensures that things get resolved in a timely manner and induces communication between all parties.

6.0 Design and Construction Overview:

6.1 Construction Sequence:

The project schedule is basically as shown on the grant chat shown in Appendix A which illustrates the major phases of construction starting from obtaining the permit until substantial completion. However, since the project is an expansion of an existing plant which runs 24/7, there were a lot of requirements, issues and conditions that had to be done and maintained throughout the project which dictated the flow of the project schedule and caused major changes in the schedule. The Project schedule that is shown in Appendix A refers to the bid schedule and not the current schedule, and since it has been modified and changes are still taking place; the bid schedule would give a good description on what the project schedule is actually like less the date changes. Maintaining operating plant access, employee entrances, roadways and so on had to be taken into account in planning all of the site improvements to minimize the impacts to daily operations.

6.1.1 Foundation/ Site work Sequence:

The first step in the foundation sequencing plan was to relocate Truck staging to an area to the east of the plant's boundaries right next to the old parking lot. After which, new access roads would be created in addition to a new parking lot and a stone construction support area. With that being done, excavation and foundation work can start. Site topography dictated that the basement and the new access road be excavated to provide fill material for the building footprint. In addition, the deep excavation at the basement and near the new plant entrance required rock blasting.

6.1.2 Building Erection Sequence:

Initial building construction as envisioned to run from south to north starting with the Basement {A-E, E-H.9, H.9-P then P-Q}. Due to cost consideration the north wall of the basement was not designed as a retaining wall. Consequently, they had to erect the entire south section of the building (A-E) from Basement to the roof, with cranes working on the south and north sides of the footprint. Cranes working on the north side of the basement precluded them from installing foundations just north of the basement. Rather than incur the downtime to install foundations (with curing) and the geo-grid backfill assembly in this area, they altered the construction sequence to run {A-E, Q-P, P-H.9 then H.9-E}.

To recoup some schedule time lost during preconstruction (due to the changes in scope), the precast erection was bought utilizing (2) cranes to cut their installation schedule from 22 weeks to 12 weeks. While the basement area (A-E) was erected from outside the footprint, the area (E-Q) was erected from inside the footprint. Their erection sequence (and requirements for crane roads / delivery access, etc) drove the installation of the Underslab plumbing and foundation concrete work for this area (E-Q).

6.1.3 Finishing sequence:

Finishing in this project refers to bringing in the plant equipment; and this will occur as soon as the building envelope is constructed and completed. There is no directional sequencing for the finishing stage as some things will be installed and finished before others. It depends on the location and the strategy on how to bring in the equipment. For instance, to facilitate easier installation of Fuala's large ingredient silos this area of the building and the adjoining Rail Receiving areas were changed from a precast concrete structure/walls to steel, metal deck and insulated metal panel walls. So rather than having this area erected 1st (in the south to north approach), the Silo and Rail areas are being completed last after equipment installation. This seriously complicated the installation of overhead MEP rough-in above the silos, requiring scaffolding to be erected over the entire area which has delayed completion of work close to a month.

6.2 Building Systems

Scope of Work	Yes	No
Demolition	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	X	

6.2.1 Demolition and site work:

The West plant expansion does not have major demolition phases. Basically, the parking to the east of the plant has to be removed and done once again in order to comply with new requirements and codes. Otherwise, the rest of the work before excavation was due to building new access roads, Plantation, open spaced area to support the construction phase and create a new parking lot to the west of the plant.

6.2.2 Structural Steel Fame:

The west plant expansion does not have any steel structural frame for the main building envelope; the only area where structural steel is used is within the building for the mezzanine. Most of the structural steel is used in the main mezzanine in area's F, D, B. The other area where the hollow structural section is used is along the mezzanine elevated pathway from O to B in addition to smaller mezzanine area all around the plant. The mezzanine is held up by attaching the hollow structural section to the precast walls of the building envelope. The Hollow structural sections run along the west-east direction in addition to the frame around the mezzanine.

6.2.3 Cast in Place Concrete:

Cast in Place concrete has been used moderately throughout the building. Starting from bottom to top, the basement has a cast in place foundations and walls all around in addition to cast in place slab on grade. The Mezzanine is also a slab on grade on metal deck, which is held by the Hollow structural section as mentioned earlier in the structural steel frame section. The SOG for the foundation is placed on top of the crushed stone base. All CIP concrete is to be air entrained with 4000psi at 28 days. Concrete will be pumped using pump trucks.

6.2.4 Precast Concrete:

The building envelope consists on precast panel walls all around the west plant expansion including the eastern wall that connects the new addition to the old plant. The basement is supported by mostly by 24x24 precast concrete columns in addition to other sizes. Those precast column hold the first floor which is also a precast concrete structure that has 4" reinforced topping slab. 24x24 precast concrete columns are also used in the first floor to hold the structure and the roof. The precast columns and walls on the first floor support the mezzanine steel structure. The roof is a precast concrete T beams below the EPDM with insulation.

6.2.5 Mechanical System:

The mechanical system is placed in the southwestern part of the building (Area I) in the basement level of the west plant on a raised concrete pad. The overall HVAC system will feature a total of 32 VAV reheat units serving the entire west plant providing air at 180F. The reheat system ranges from 150 CFM up to 2400 CFM. The Cooling systems will be placed on the roof and will supply air at 42 F. There are 13 air handling units placed on the roof and 2 air handling exchangers.

6.2.6 Electrical System:

A new utility building will be created along with the new west plant expansion. This utility will have a new 69KV feeder along with the original 69KV feeder; this will generate a total of 1200 Amps (600 from each) that will feed into the plant from PPL. The 2 service entrances will be feeding 4 substations through distribution panels running a 3phase (4-wire) 277/480V circuit. In addition, each substation will have 2 backup generators running at 450KW – 562.5KVA.

As for the lighting systems, the entire building will have florescent lighting all over. They are all consistent and are uniform throughout the plant from the basement and up to the mezzanine. The fixtures will be T8 lamps and electronic ballasts. In addition, there are 2 back generators at each of the 4 substations that will activate upon loss of power.

6.2.7Support of Excavation:

Since the information was not found in the civil drawings. The following is an assumption of what could be the support of excavation until further verification is done.
As for the support for the excavation, shoring will be used to keep the excavated area in place after which the foundation phase should begin. Underpinning of the existing structure would also be done with extra care and support to hold the existing plant and prevent it from collapsing. In addition, if dewater would be required, standby pumps would be used to complete the task although no problem has been reported regarding the dewatering system.

6.3 Detailed Structural System Estimate:

The West plant expansion's structural system consists of 3 systems mainly: Precast Concrete, Cast-In-Place Concrete & Steel members. The Foundation of the plant would be a Cast-in-place concrete foundation which includes the Spread Footings, Continuous footing, Foundation Walls and Slab on Grade foundation. The exterior Walls of the plant starting from ground level and upwards would consist of precast walls which do not exceed a width of 12 feet. The precast walls would be set next to each other all around the expansion. The roof of the basement would consist of precast double Tees with a span of 32 feet while the roof of the entire plant (first floor roof) would consist of Double Tees with a 64 feet span. The basement which would have a precast roof would also have a 4" topping slab reinforced with 4x4 @2.9 x W2.9 WWF. The area of the first floor that is over the basement would have a precast structure with 4" concrete topping; the rest of the first floor area (which has no basement) would have a 6" Shrinkage compensating Slab on Grade reinforced with 6x6 W6.0xW6.0 WWF. In addition, the first floor and roof are held by long 24'x24' typical precast columns all over the plant. The Area where most of the structural steel members were used at is the Mezzanine level which can be found over area's B, D, F & H in addition to the framing place of areas I and J. The steel members used in the expansion are mostly Hollow steel structures for the mezzanine and a few Wide flange beams for the roof framing.

The detailed structural estimate in Appendix B shows the breakdown of the costs of the 3 systems mentioned above. The Cast-in Place concrete and precast concrete estimate was placed together while the Steel estimate was placed in another. The estimate was found using a mix of methods which produced the final estimate. The area calculations for the estimate, which can be seen in the concrete tables, were found using Adobe Acrobat 8 Professional area calculation tool. The number of steel members and the precast double tees were found by counting them piece by piece from the drawings provided. The online RS means program, Cost works, was used to transform the total count of steel members and the total volume of concrete into prices that would include all requirements up to Overhead & Profit unless otherwise noted in the assumptions.

The estimate cost turned out to be lower than the actual cost. This can be for many reasons and they are as such: The RS means prices do not reflect the actual cost since each project has its own bid of costs, the exact same members could not be found in the RS means in which the closest option was chosen which could greatly change the costs produces especially in the cast of the steel and precast members, The actual estimate is a comprehensive estimate of all items in its division which is not the case with the estimate since in this case the actual cost of Steel includes all metals in the building while the estimate only reflect the main steel members used.

SYSTEM COST	Estimated	Actual
Concrete	9,649,684	12,735,300
Metals	1,388,187	4,631,919
TOTAL COST	11,037,871	17,367,219

For the Cast-in-Place concrete, the assumptions were as follows:

- The foundation wall is a CIP structure, but the exact details were not found in the RS means in which the estimate provided in Appendix B is actually for a "free-standing wall'
- Most of the members in using in the plant, such as S.O.G. thickness, foundation thickness, footing dimensions and so on could not be found exact in the RS means estimate book in which the closest option was chosen to minimize difference in cost.
- Since counting rebar and WWF in the cast-in-place concrete, in order to find the weight and eventually find the cost, would be a tedious task; it was calculated with a ratio. The only unit estimate within the CIP estimate that had forms, reinforcing steel, concrete place and finishing cost all at once was the 'Free standing wall' mentioned earlier which is in lieu of the foundation wall. The rest of the prices did not include any and as mentioned by Dave Holbert , a guest speaker that came in Thesis class AE 481, and other sources; the material cost of concrete is only around 30% of the total cost which includes the rest of the expenses.

For the Precast Structures:

- The same thing was done with precast regarding picking the option in the RS means that is closest of the member; however, the options were not as close as the CIP estimate so it will have an even less accuracy than the CIP.

- The precast 24’x24’ column cost was estimated since within a typical bay (32’x32’ which can be seen in Figure 6.3) there are 4 columns and 4 spread footings. However, since each column spans 4 areas, then only ¼ of a column actually holds the load of the typical bay along with 4 other columns. Same thing applies for the spread footings placed below the precast columns. Hence, there is exactly 1 column and 1 spread footing for each typical bay. Through this calculation, the number of columns and spread footing was found by dividing the entire area of the expansion by the typical bay area.

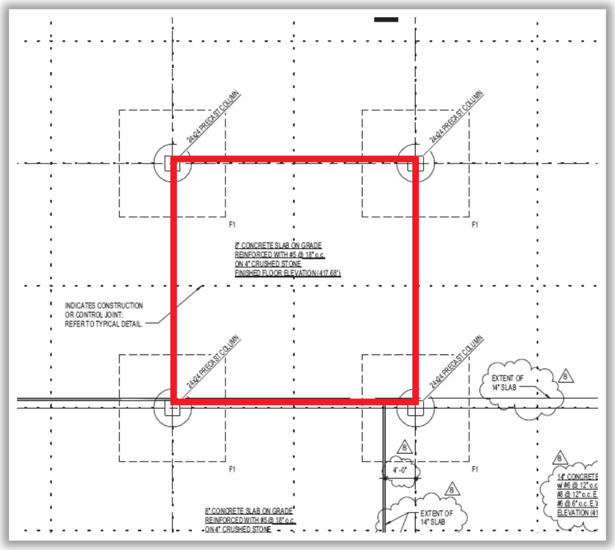


Figure 6.3 – Typical Bay

- 24’x24’ Precast columns estimate is not available in the RS means; instead there were only 1 close option which stated “precast column, large, square, up to 24’” which does not describe the precast columns used in the plant. It was also in term of LF so the estimate was done by counting the number of columns which was then multiplied by the height.

As for the Steel estimate:

- Since there no information provided regarding HSS structures in the RS means; the information was brought from the McGill University Website: "http://www.cim.mcgill.ca/~paul/HollowStruct.pdf"
- Most of the actual W steel members used in the plant were not found in the RS means; and so the closest option which would produce a close cost estimate was chosen.
- Since HSS costs are not in the RS means; the cost of the material and its installation was assumed to be like cost of W members. Hence, the ratio of weight of steel of the W members to the cost produced by the RS means Costwork was used to estimate the cost of HHS from its weight.

Since the each area in the plant is different from the other, finding a typical bay and estimating its cost and then estimating the cost compared to the entire building was not possible. Hence, the estimate was done by breaking the plant into 2 zones where so a greater extent, the structural design between the areas in each zone was similar which will produce more accurate results.

Zone A consists of the areas which do not have a basement which are areas A, B, C, D, E, F. Zone B consists of the areas which do have basement which are area G, H, I and J. Within these zones, the areas have different members all over; and so, the details that were chosen to produce the preliminary numbers are the most repetitive and closest option which can be applied to all details chosen. Figure 6.4 below shows the Areas mentioned above.

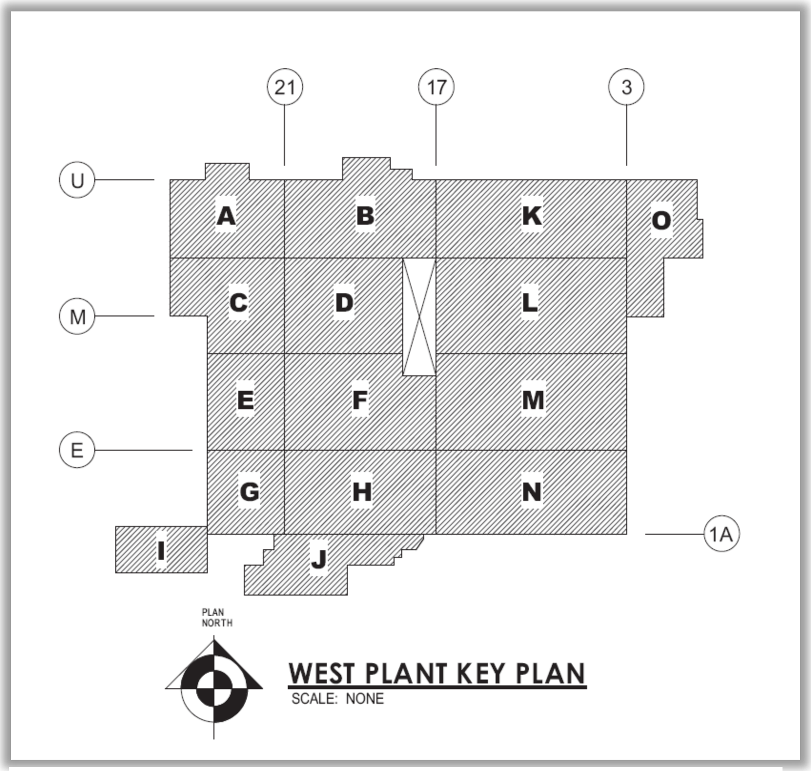


Figure 6.4: Overall Key Plan

6.4 Project Cost Evaluations:

The following section will show different types of estimates and how they differ from the actual costs. In addition, a breakdown of the cost relative to each trade will be shown.

Table 1 : Gross Building Area by Floor

Basement	76,353 SF
1st Floor	207,765 SF
Mezzanine	40,285 SF
TOTAL	324,403 SF

As a result of drastic changes in the scope of work, the overall building cost and cost per square foot has increased as it can be seen in Table 2.

Table 2: Basic Overall Cost Information

Type	**Original Estimate**		**Current Estimate**	
	Cost ($)	Cost/SF ($/SF)	Cost ($)	Cost/SF ($/SF)
Construction Cost (CC)	$35,110,000	$108.23	$56,481,000	$174.11
Total Cost (TC)	$53,657,000	$165.40	$83,166,000	$255.85

Table 3: Major Building Trades' Cost

Trade Name	Trade Cost ($k)
General Condition	$12,681
Site work/site utilities	$8,334
Landscaping & planting	$183
Concrete	$12,987
Steel & Metals	$6,578
Roofing & Waterproofing	$2,180
General Construction	$5,384
Acid brick Flooring	$500
Pre-Engineered Structure	$87
Elevators & Escalators	$590
Fire Protection	$1,612
Plumbing	$2,504
Refrigeration	$2,215
HVAC & Sheet metal	$15,138
Testing & Balancing	$108
ATC	$1,438
Electrical	$9,909

6.4.1 RS Means Square Foot Estimate

Using the online Costworks software from the RS means website, a square foot estimate was developed. However, a factory with the exact same characteristics as the Fuala plant expansion was not found; hence, the Estimate that was taken was for a factory was for 1 story only when the actual building had a mezzanine and a basement. However, the area used for the RS means estimate was not for the first floor but was actually the cumulative gross square foot area of the entire plant; this was accommodate for the basement and mezzanine that were not included in the story height calculation. In addition, the location adjustment factor was specified for a nearby city since the actual city was not listed. The values used in the software are as of 3rd Quarter of 2011. (See Appendix C)

Table 4: RS Means Estimate Summary	
Stories	1 Floor
Perimeter	2407 ft
Story Height	33 ft
Floor Area	324,403 SF
Cost/SF	$98.31
Construction Cost	$31,892,500

6.4.2 RS Means MEP Assembly Cost Estimate:

The table below shows the approximate cost through an assembly estimate using the RS Means Assembly cost book. Although not every detail of the MEP systems went into the estimate; however, the main systems were included in the estimate as it can be seen in Appendix G. So this provides an overall estimate of the systems that were used and their approximate cost.

Table 5: RS Means MEP Assembly Estimate Summary	
Mechanical	$10,825,328.11
Electrical & Telecommunication	$7,521,428
Plumbing	$352,809.3

6.4.3 Cost Comparison:

Table 6: Actual vs SQFT Estimated Summary of overall building cost		
Estimate Type	Actual	RS Mean SQFT Estimate
Cost/SF	$174.11	$98.31
Construction Cost	$56,481,000	$31,892,500

RS means does not account for site work, fees, contingencies, insurances and so on. Hence, the Construction cost was compared instead of the Total Actual Cost. As it can be seen, there is a difference of $24,588,500 between the actual and the RS Means SQFT estimate. The reason for the big difference in cost is firstly because the RS Means SQFT calculation is an estimate; which means that there it is a calculation of very low accuracy. As for the reason for the big difference, the calculation made in the RS means relies on area, perimeter, story height and location; with that being said, the list of options of characteristics of the building being estimates is not even close to the actual building characteristics.

Table 7: Actual vs. Estimated Assembly Summary		
	Actual	Assembly Estimate
Mechanical	$15,138,000	$10,825,328.11
Electrical & Telecommunication	$9,909,000	$7,521,428
Plumbing	$2,504,000	$352,809.3

The table above shows the difference between the actual cost of the MEP system and the estimate cost through the RS Means Assembly estimate. It is a closer estimate to the actual value when compared to the RS Means SQFT estimate, and that is because there is more detail and accuracy when calculating the systems that are included. However, as it can be seen, the numbers still have a gap between them and that is due to the fact that the systems used could not all be found in the RS Means Assembly book and in many case, and so the system that is closed to the actual was chosen and assumed. These minor assumptions can cause drastic differences in the costs.

With all that difference, the Assembly was a good estimate that does what it is intended to do which is provide an close estimate to the building system that is wanted.

6.5 Site Plan of Existing Conditions

Image 6.5: Site Plan bird View

The aerial photograph shown above, provided by *Bing*, shows the site prior to the beginning of construction. The new west plant expansion will be constructed on the large area to the west of the original plant. The addition itself would be around two times the size of the old plant where it would be connected to the existing plant. The new addition will require the construction of new access roads with truck and employee parking areas. The existing site utilities will be extended to provide service to the new facility. The existing conditions and utilities could be seen in Appendix D.

The site has no structures in the in its vicinity except for the original plant. It is an isolated site with two main roadways that extend from the southwestern corner of the plant; a road with 2 lanes going both ways from the north and a smaller road with 1 lane going both ways from the south.

There is no foreign traffic coming anywhere near the factory. The only 2 types of people entering are : factory works that enter the factory from the southern road and park on the east side of the existing structure and will be able to get into the factory via a fenced path; Construction personnel and vehicles that enter the site from the Northern road.

Basically, Turner can manage the construction without having to deal with any interference from the surrounding since it is a fairly isolated site.

6.6 Local Conditions:

Even though the local area is commonly known for using structural steel for structural systems, the plant's west plant expansion is designed to have a concrete shell with the mezzanine being the only steel structure. Due to the isolated location of the plant, the project site has a large area available in which a large parking lot has been created for the contractors in addition to trailer spaces and a 'construction support area'. The only issue with parking was that parking had to be provided for plant workers where it was relocated twice to accommodate for the construction process and reworking the existing parking lot for the workers. As for recycling, up to 70% of non-hazardous construction and demolition debris will be recycled or salvaged.

Due to the site's proximity to a former landfill operation; Turner investigated and generated "Site Phase 1 Environmental Assessment" which was done to identify the exact level of hazard, potential soil vapor impacts primarily methane. As a result a total of eighteen borings were completed onsite with fourteen completed within or directly adjacent to the proposed expansion footprint and four completed to the west of the proposed work area spanning the northern and southern extent of the proposed work. The locations of the borings can be seen in the picture below.

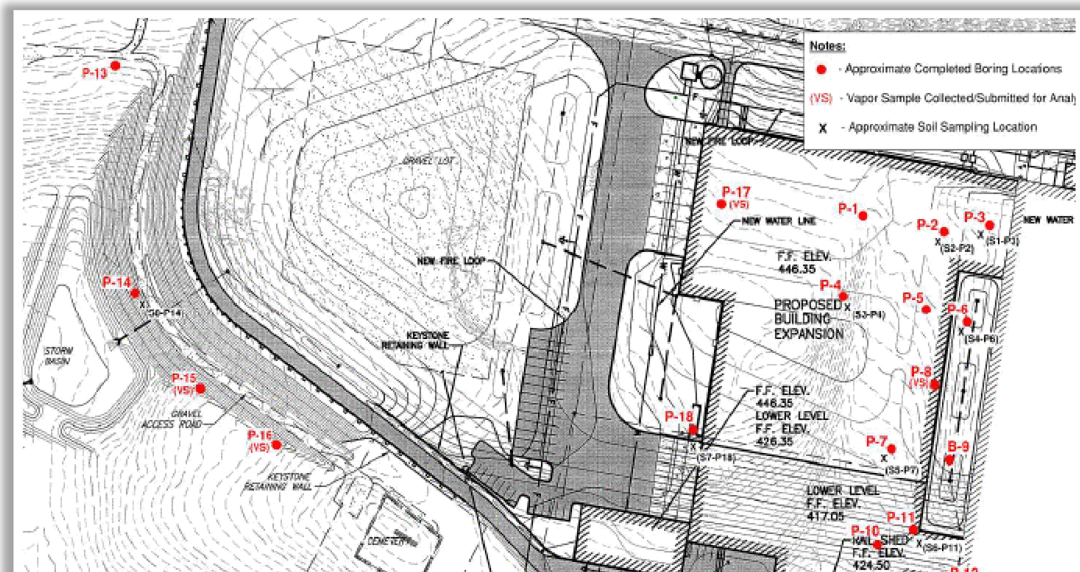


Image 6.6: Local Conditions

The lower explosive level (LEL) of methane is 5% and OSHA calls for an action level at 10% of this level or 0.5%. One of the samples had a methane result of 0.33%, or about 70% of the action level. This methane concentration suggests there is a potential to encounter methane concentrations at or above the action level during construction and thus this should be incorporated into Turner's Site-Specific Health and Safety Plan for the project.

6.7 Detailed Project Schedule:

The project schedule is basically as shown on the grant chat shown in Appendix F which illustrates the major phases of construction starting from obtaining the permit until substantial completion. However, since the project is an expansion of an existing plant which runs 24/7, there were a lot of requirements, issues and conditions that had to be done and maintained throughout the project which dictated the flow of the project schedule and caused major changes in the schedule. Maintaining operating plant access, employee entrances, roadways and so on had to be taken into account in planning all of the site improvements to minimize the impacts to daily operations.

The schedule is Technical Assignment 1 provides a broad understanding of how the construction process of the project will take place. This Detailed Project Schedule would show a more comprehensive breakdown of the tasks that will take place starting from the very first stages of Design Development. In that phase, all the drawings and designs would have to be prepared, bid and awarded separately. After which, the second stage can begin which is the package procurement and the fabrication and delivery as required per trade.

The third Stage would be the actual beginning of the construction which would commence by installing a fence and following by bulk excavation. Following the earthwork stage, the process of laying down the foundations and superstructure begins by pouring concrete Mat Foundation, wall strips and column footings. The sequence of placing the plant foundation would take place from south to north starting with the basement, which as mentioned in technical report1 would have an area of $1/4^{th}$ the main floor and is at the southern end of the building.

After foundations have been placed, erection of the structural system of the building enclosure; from precast walls, columns and slabs; would take place in the following sequence as seen in the schedule: east to west (17 to 23), and south to north (A – U). All the other trades follow the same sequence, except in a few cases such as in Plumbing were there was a Silo Area, Mould Wash, Rail Receiving, Lecithin before the basement and level 1 area were done.

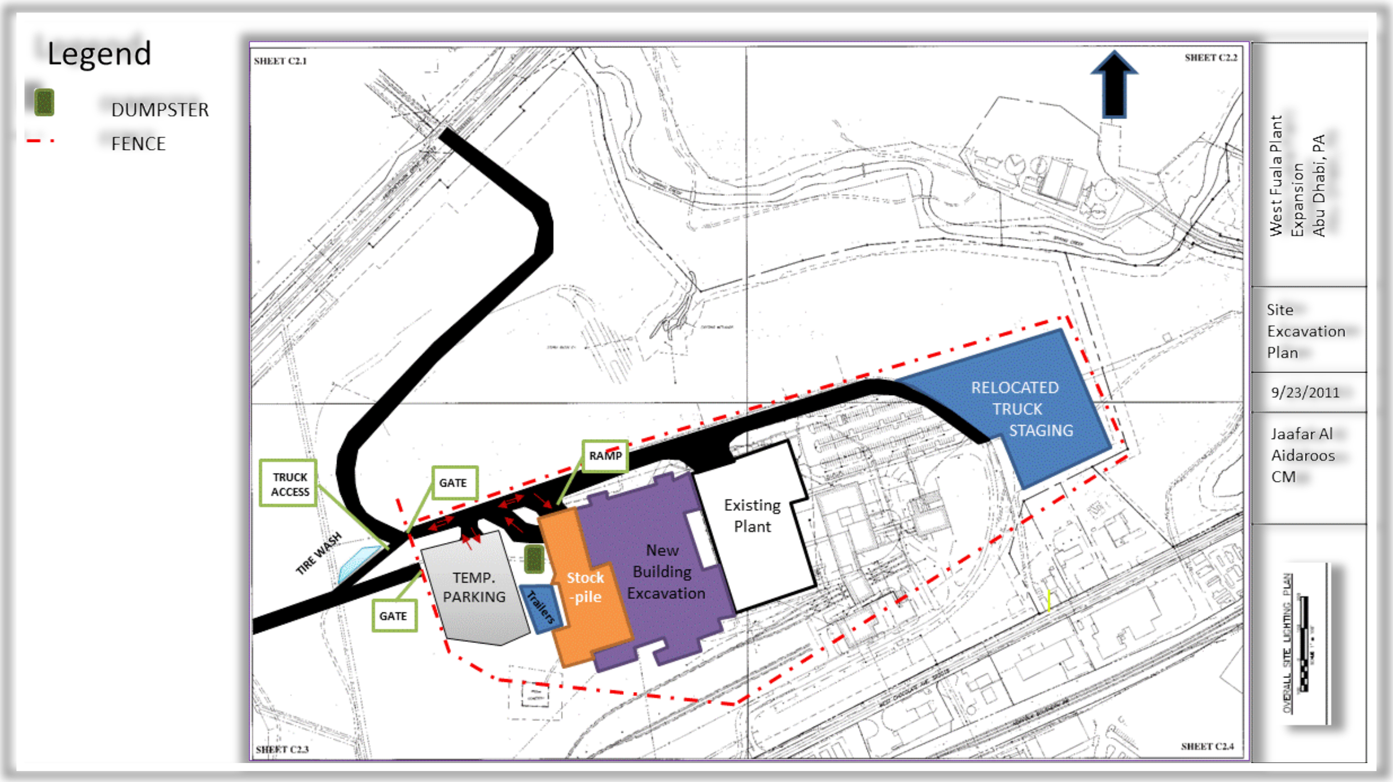
The schedule has been broken down into many divisions in many levels in order to make the schedule readable and understandable with ease.

Notes: Some tasks were not broken down as it would be expected since their details were not as important as the other information that were mentioned (Package Procurement & Engineering: Develop bid package, bid, award, shop drawings, Material Fabrication & Delivery).

Other tasks which have a (“) implies that the sequence is the same as the previous task/trade, and including the details again would be a matter of impractical repetition.

6.8 Site Layout plans:

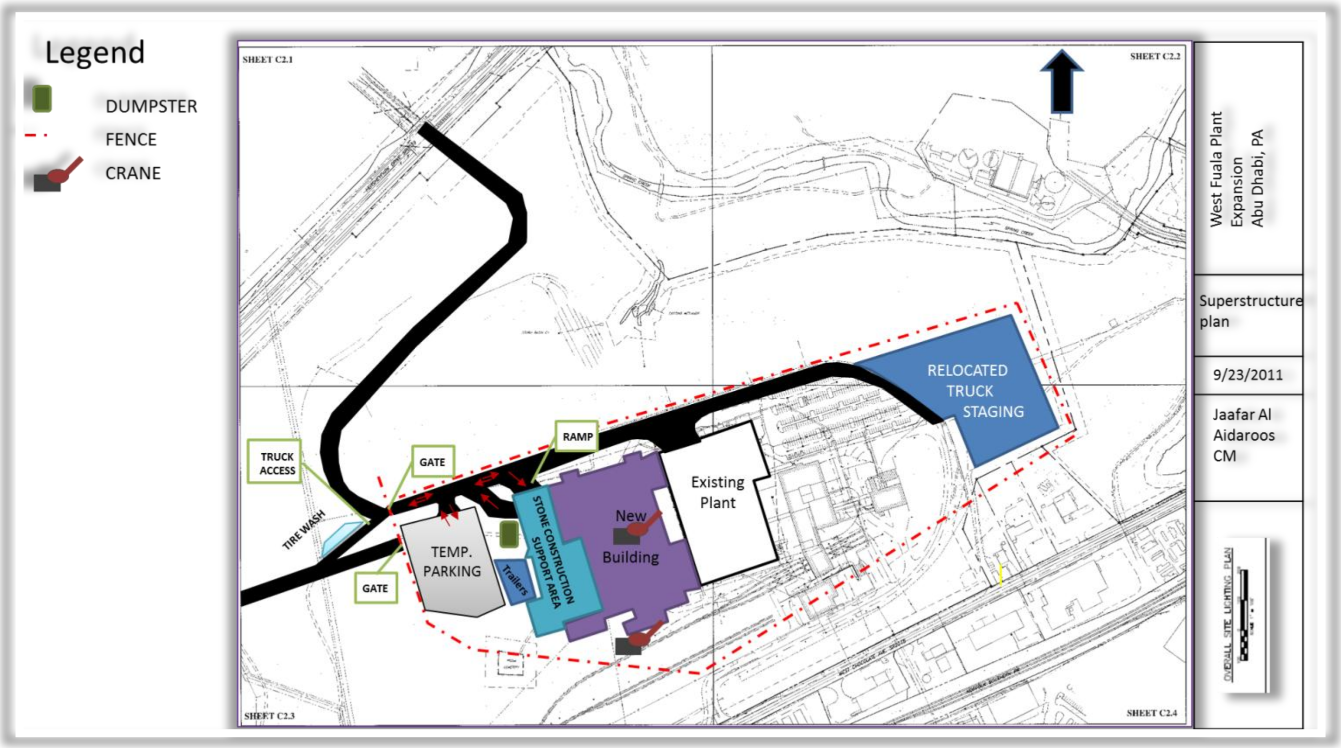
Excavation Plan



At first, Site work had to be done before the excavation phase could start. Access roads were created from the North side that would connect to the road; this would be used as the supply access road for trucks, construction vehicles and delivery of materials. A temporary parking lot was established to the west of the west plant in addition to an open area (Marked in orange). In addition, Truck staging was relocated to the east of the old plant. After which, the excavation process can begin.

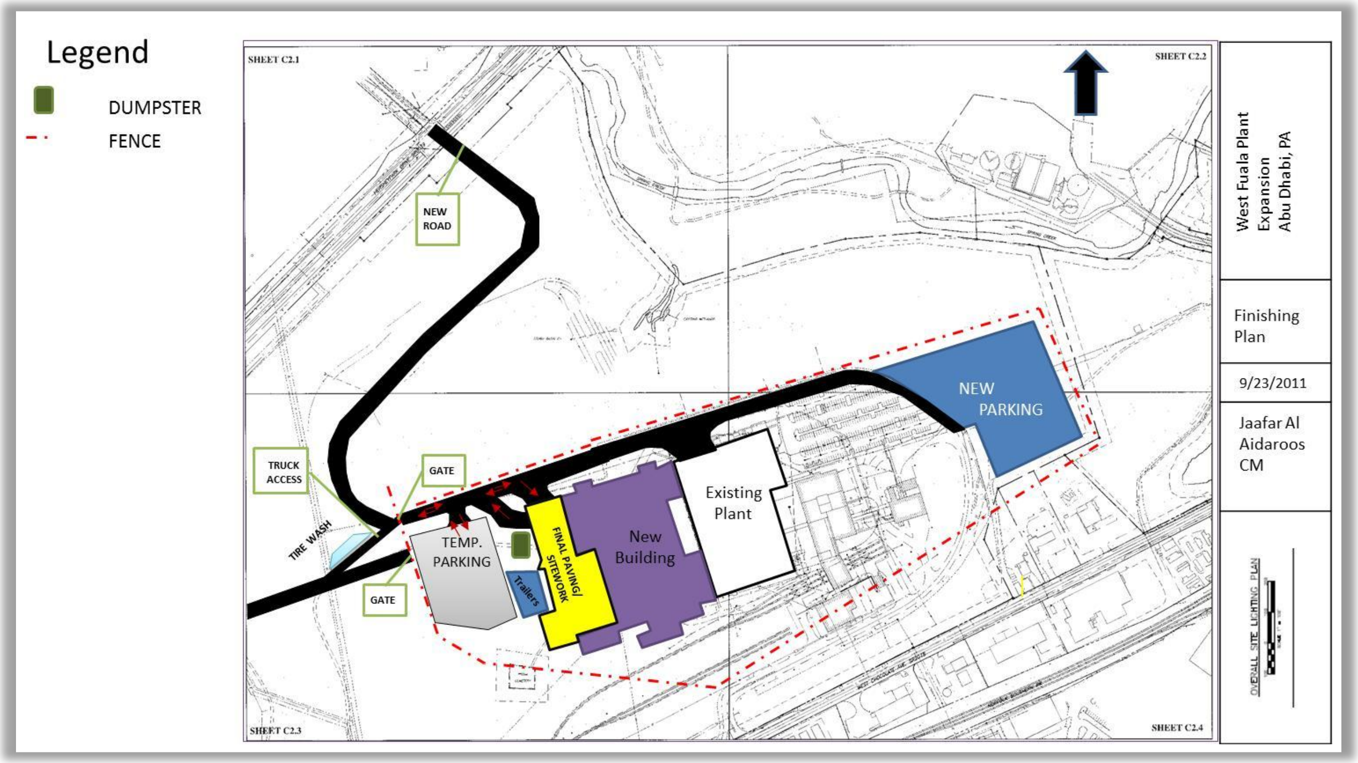
As for the layout critique, the north road is very essential for delivery purposes especially that the southern entrance is still being used by the workers in the original plant on a daily basis. In addition, the north access will be used in the future even after the construction project is complete where traffic will be much smother especially that a larger plant means more workers.

Superstructure Plan



In the superstructure phase most of the site work is completed and all the work that is required will be around and within the structure. The stockpile area can still be used as a stockpile area where it is labeled in the plan above as 'Stone Construction Support Area'; however, since the building floor has been constructed the materials can now be placed in and around the structure. The crane for the erection of the precast panels will start from the south to the north; hence, one of the cranes was located below the building where it will start placing the precast concrete in place while the other crane works on the north side. Afterwards, the crane in the center of the structure would erect the central area while backing up to finish the superstructure erection process.

Finishing plan:



The final phase would be the finishing stage where all the work would be within the structure. The area that was used as a support for construction (in yellow) would eventually become a parking lot; hence, the paving and sitework phase begins in that area. In addition, the parking lot to the east of the plant would be reconstructed and completed to provide a new parking area for the workers while the construction process is still taking place and for after the completion of the project. All sitework would be finalized and completed.

See Appendix E for 11” x 17”

6.9 General Conditions Estimate:

The General Conditions Estimate is broken down into 2 parts. First of is Personnel Expenses, which includes the main staff working on the project such as the project executive, Senior Project Manager, MEP coordinator, Cost Engineer and so on. The second part of the general conditions estimate would include the Non-personnel expenses which are the Field Office expenses, Temporary facilities and Miscellaneous Costs. An example of such expenses would be project signs, office trailer set up, electric consumption, progress photos and much more as will be seen in Appendix H.

The First part of the estimate which is the primary personnel was created using the organization chart of the Project team where nearly all staff was included in the Primary personnel estimate except for a few members in which their positions were not found in the RS means, which was the source of the estimate.

The non-personnel expenses is a more bigger estimate since it includes more factors that contribute and sum up the general conditions cost. Since not all items in the actual general conditions and general requirements could be found in the RS means and vice versa, a lot of information was closely estimated. Moreover, some estimates were not in the actual general condition in which other things were added instead in order to keep the estimate as close and as realistic as possible.

General Conditions Estimate	
Non Personnel Expenses	$56,410.00
Primary Personnel	$3,542,000.00
TOTAL	$3,598,410.00

GC non Personnel Actual vs. Estimated	
Actual Cost	Estimated Cost
$990,000.00	$596,305.00

The actual ‘non Personnel’ costs turned out to be much higher than the estimated. There are many factors that contribute to this result; first off which is the fact that not all conditions and requirements were found in the RS means. In addition, most of the costs, even if they were available in the RS means, would have different values and prices. The RS mean’s purpose is to provide an approximate of the general conditions cost which is purpose of this section which can be seen in Appendix H.

6.10 LEED Evaluation:

The West Fuala Plant Expansion couldn't achieve any LEED certifications through the U.S. Green Building Council (USGBC). Going through information provided from drawings to specification books and from emails to site visits, a rough draft of a LEED Scorecard was developed. The findings show that the project could have been on its way to achieve a Silver LEED certification if all potential points applied.

Sustainable Sites:
The project could earn a minimum of seven points in the category of sustainable sites. While there are two more potential points in storm water design quality control and roof heat island effect. The project only needs to be verified and evaluated for those two potential points. If that was accomplished, they would get a total of 9 points in the category.

Water Efficiency:
The plant expansion is doing great efforts in terms of this category in particular. It's only two points away from achieving the maximum possible points in the category. The project doesn't use any potable water for irrigation. The fixtures in the new expansion can reduce the up to 30% which allow gaining two points. To get the other two in this sub-category, the fixtures in the existing building have to be replaced to get a minimum of 40% reduction of water use in the entire building (including the expansion). Also, the project can employ rainwater harvesting management plan to obtain a 50% water use reduction to get a possible two points in the innovative wastewater technologies sub-category. Unfortunately, the payback period to achieve that is relatively long. So, due to the tight budget, they will have to reconsider spending to employ the requirements to get the four potential points.

Energy & Atmosphere:
This can be the toughest LEED category on the plant. The reason can be obvious, which is the nature of a factory building that has a high consumption of energy and can have some effects on the surrounding environment. Some sub-categories are difficult to achieve because the existing facility has to meet the new requirements of LEED. For example, the existing HVAC equipment has to be verified with the new requirements. Another point is the building can't achieve the enhanced refrigerant management that disallows or limits the use of refrigerants that has global warming effects potentials. That is because of the existing systems that have to be included in the evaluation. On the other hand, there are about 8 potential points. The expansion tends to get points in green power, measurement and verification (with the confirmation of existing system monitoring capabilities), and enhanced commissioning sub-categories.

Materials & Resources:
The expansion can achieve a total of 10 points out of 14 points in the Materials & Resources category. The project can achieve 97% in maintain existing walls, floors, and roof which gives three LEED points. Moreover, the project employed a construction waste management plan that allowed it to achieve a 70% of recycling non-hazardous construction and demolition debris. Recycling a high quantity of steel made a 20%, of the steel total cost, achievable to gain two more points in recycled content sub-category. One more point can be achievable due to the relatively low project cost in the certified wood sub category (small amount of wood can be certified).

Indoor Environmental Quality:
For this category, the expansion couldn't get as many points due to the expansion nature being a factory facility. The expansion lost about seven points in this category. That is because of impracticality and ineffective methods in industrial facilities and production areas; whereas there are five achievable points and three potential points. The first five can be achieved in the following sub-categories: outdoor air delivery monitoring sub-category by incorporating the monitoring and alarm systems as part of BMS with the need of the confirmation of the existing system capability; employing a construction indoor air quality (IAQ) management plan with a relatively small cost; using low-emitting materials (adhesives, sealants, paints, and coatings) in all interior applications. The following sub-categories can get the project 3 more potential points: using low-emitting materials in flooring systems; indoor chemical and pollutant source control by providing entrance floor systems, isolating chemical areas, and filtration of disposal chemical; thermal comfort verification by conducting a thermal comfort survey of the building occupants 6-18 months after occupancy.

Innovation in Design:
The West Fuala Plant Expansion can be considered as an innovative building since it has achieved five out of six points in the innovation in design category. It achieved that by applying the following strategies: using 30% of material cost in the project in materials extracted, harvested, recovered and manufactured within 500 miles of the project location; using 95% of certified wood by the Forest Stewardship Council criteria on the project; maximizing open space; having at least one accredited LEED professional participating on the project team.

Regional Priority Credits:
As mentioned earlier, the nature of this project being a factory facility limited getting some environmental-related points and made some categories/sub-categories hard to fully or partially comply with and this is one of those categories. The project missed four out of six possible points due to the unqualified existing building as well as its location between two independent routes. The only point from the two potential points that tend to be achievable is the associated with storm water quality control, but the site final design still needs to be confirmed.

6.11 BIM Evaluation:

Although a lot of benefits and advantages come by default with the use of Building information modeling, the main reason for the use of BIM in this project is mostly for clash detection between the trades.

Initially, the architect created the complete BIM model first in Autodesk Revit Architecture and Revit MEP. It included the architectural, structural and MEP models. This was then converted by the BIM coordinator to .DWG files which was used to create the Navisworks model. Whenever there would be an update, the architect would provide the BIM coordinator with an updated Revit model.

Integration and implementation of BIM for the west plant expansion was conducted by weekly meetings. The BIM coordinator would host a coordination meeting between him and the electrical, mechanical, plumbing, fire protection and process equipment subcontractors. They would then evaluate clashes that the BIM coordinator would report that have been found between their models. The clash report would be performed using Autodesk Navisworks Manage (software).

Each of the subcontractors is responsible for correcting their clashes by next week's meeting. Once a certain area of the building is 'clash-free' where the problems have been addressed, they would then sign off agreeing that that section of the model has been coordinated and if conflicts arise in the field, it is the subcontractors' responsibility to review the model and see who is correct and who is wrong.

BIM will also be used to help the owner coordinate their process equipment. By looking at the model, the owner would be able to see where there are clearance issues with their equipment. At the end of the project, Turner is planning on turning over the model to the owner so that he can use it for facilities management purposes (storage of O&M manuals, warranties, record drawings, shop drawings, etc).

The way BIM was used in this project is for its most basic advantages which are clash detection and solving problems ahead of time. In addition, the way it was implemented was very organized where there were weekly meeting between the main subcontracts and each side had their responsibilities fairs and logically. Another way where BIM was used is Asset management where the owner would be able to use it for the maintenance and operation of the plant.

However, there were other benefits that could have been taken advantage of such as Engineering Analysis which could help improve the project design. For instance it can improve the energy consumption of the plant in addition to the quality of the building services provided. BIM could have also been used to for 'Building Systems Analysis' which is a process that compares the design specification to the actual building performance. With that, the construction faults can be detected and solved.

7.0 Analysis 1: Conceptual Energy Modeling for Early Design Decisions

7.0 Problem Identification:

The initial Fuala plant has operated for around 100 years and has delivered products for all that duration. The west Fuala plant expansion will take the role of the original facility of operating 24/7 to produce the major good to be sold around the globe; hence, it would be very important, helpful and beneficial for the owner and the process engineering team overlooking the equipment and its facility to study the energy costs of production, efficiency and effectiveness of the equipment and process being used.

7.0.1Goal:

The goal of this analysis would be to understand the effect of Conceptual Energy modeling for early design decision making. The method of conducting this would be explored in addition to cost, schedule and possible design changes that would affect and change the design of the building to better result.

7.0.2 Procedure:

- Find out the necessary tools needed to perform this analysis
- Study and understand the program and possible design change
- Conduct a solar study using the program
- Recommend a design change through the use of Energy Analysis

7.0.3 Possible Resources:

- Auto-Desk Project Vasari
- Educational Background from previous AE courses
- PSU AE faculty
- Engineering Library
- Online resources

7.0.4 Projected outcome:

The anticipated outcome of this analysis would be that applying Energy analysis to a project and then delivering it to the owner would have many advantages that the owner and the facility management team would benefit from in the long run in addition to the benefits that will be achieved in the design development phase.

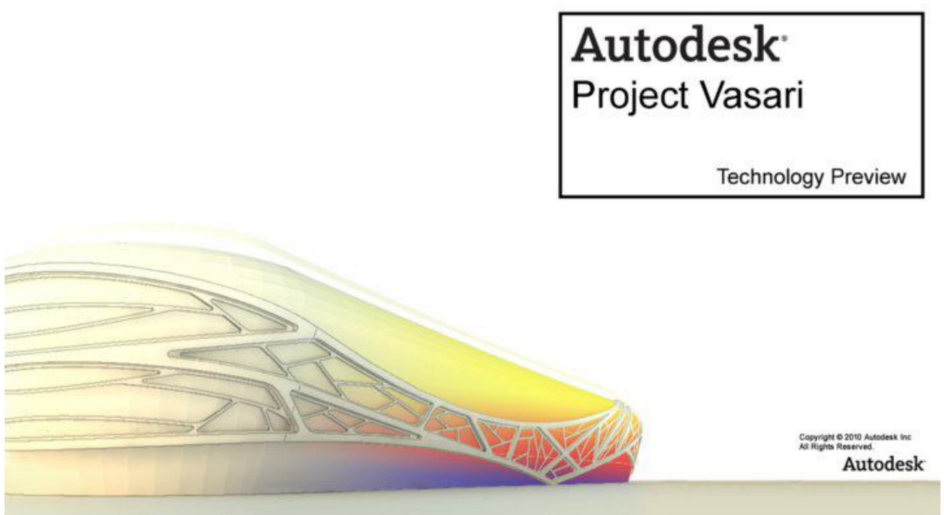
7.1 Background information:

This analysis will assess the benefits and advantages of Energy Analysis, a branch of Engineering Analysis, on a short term basis for predesigning purposed. Energy analysis will be performed using the program “*AutoDesk - Project Vasari 2.0*” which is, as mentioned on the AutoDesk Labs website, an expressive design tool for creating building concepts. It allows for integrated analysis for energy and carbon, providing design insight where the most important design decisions are made. And when it’s time to move the design to production, one can simply bring the Project Vasari design data into the *AutoDesk Revit* platform for BIM, ensuring clear execution of design intent. *Project Vasari* is focused on conceptual building design using both geometric and parametric modeling. It supports performance –based design via integrated energy modeling and analysis features.

In this analysis, a design changes would be performed; it would be conducted using *Project Vasari* which will provide information regarding the analysis performed. This information can then be used to modify the design of the building to enhance and improve the performance of the building. The energy model analysis’s purpose in this thesis is to explore the effect of utilizing conceptual energy modeling for early design decisions that can affect the energy usage of the building and then apply to achieve a building with less energy usage which will in turn produce many benefits starting with reduction of the monthly bill. This useful tool that provides fast feedback regarding each design change that occurs from the perspective of energy will be explored along with possible design changes that can be applied to the building.

Tools required to conduct the energy analysis:

- General knowledge of AutoDesk programs
- *AutoDesk Project Vasari 2.0*
- Internet connectivity to conduct the analysis through the AutoDesk database



7.2 Project Vasari Energy modeling overview:

The first step in conducting the analysis would be creating a conceptual mass using the AutoCAD tools provided in the program. Massing of the building can be a rough sketch up of the model which will produce a general analysis as requested through the information and detailed provided when running the simulations and analysis in this program. More detailed analysis and simulations can be conducted depending on the level of detail of information. For instance, once can customize and refine the detail of areas which lies within different environments within the multiple zones in the building to produce finer and more accurate results. The other option would be importing vector data, through the use of Building Information Modelling, from other CAD programs, such as AutoCAD (DWG and DXF), MicroStation (DGN), SketchUp (SKP and DWG). The most compatible version from the AutoDesk Project would be Revit which is very useful for designing the architecture, MEP and structure. Those three Revit models are enough to generate detailed analysis and simulations through the program, and through the use of BIM changes to the design can take place from the designers and engineers along with an updated simulation assessing the new design changes.

The Vasari conceptual design environment provides flexibility early in the design process for architects, structural engineers, and interior designers to express ideas and create parametric massing families that can be integrated into building information modeling (BIM). The designs created in the conceptual design environment are massing families that can be used in the Vasari project environment as the basis from which more detailed architecture can be created by applying walls, roofs, floors, and curtain systems in Autodesk Revit Architecture. This program can conduct initial rough analysis, to explore the generated effects of these parameters by creating a general model for the pre-designing stages, in addition to conducting intricate detailed analysis on a well refined and detailed model which will produce more accurate information.

This thesis analysis will explore the different design changes that can be studied or proposed for the building after conducting different analyses and simulations on a conceptual model created through AutoCAD for a fast general overview of the results and information provided from the analyses and to be able to explore possibilities of energy reduction. The following step after importing or generating the model would be setting the location for the building in the *Project Vasari* program. The location set for this project would be Abu Dhabi, PA, USA. It is very crucial to enter the location when conducting the analysis since it provides a lot of information with regard to generating location-specific shadow for view that use them, such solar studies, lighting effects, walkthroughs, project orientation, and rendered images. The location also provides a basis for weather information, which is used during conceptual energy analysis.

During the early stages of a building project, one can analyze the conceptual design to determine the use of the building (commercial, residential, or industrial), rough cost estimates for the exterior of the building, based on linear dimensions or surface area, HVAC requirements for different levels and zones of the building. Through the use of the BIM model, any change in design can be easily imported as any point to check the effect on the Energy model of the building and how the building function changed. For simplicity purposes, a solar analysis will be conducted. In addition, the model will only have 1 floor with one HVAC system for the entire building.

7.2.1 Conceptual energy modeling

The first question to be asked would be why to energy model. Using an energy model in the early design stages is very good method to many reason: firstly, it opens doors to load reduction options, by understanding the effect of different options of the building envelope and building form; it shows the effect of passive systems, such as solar radiation and ventilation; possibilities of efficient systems, such as HVAC and lighting systems; in addition to the possibility of onsite generation of sustainable energy, wind turbines, PV panels.

The way the energy model calculates is through a series of different information that is entered into the analysis in the following order: Building form, which is regarding the orientation of the building, footprint/shape, depth of plan and number of floors…; Envelope, which has to do with the insulation, percent glazing, glazing type and shading; Use and Function, from the aspect of building type, space type, occupancy; Systems, such as the HVAC system, lighting systems and equipment. The highest areas in which early designing can improve would be from the building form and envelope. Many different designs can be explored to reach the best option depending on the goals and targets of the project. In this analysis, it would be explored to see what better options should have been applied that would have reduced the energy usage of the west Fuala plant expansion. At a later stage in designing process, the systems and the use and function of the building can be explored to see better options. Image 7.2.1 in the bottom shows the Anatomy of an energy model in Vasari.

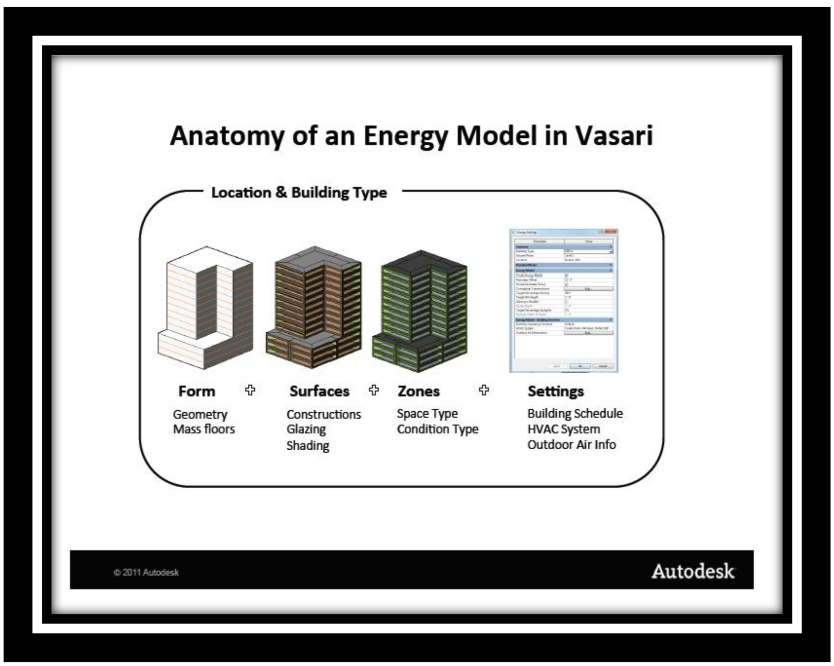


Image 7.2.1: Anatomy of an Energy Model in Vasari

7.2.2 Limitations and method of use:

With all the being said, one has to keep in mind that a conceptual energy analysis provides comparative results and not absolute energy values. It is mainly concerned with the building geometry and construction rather than mechanical systems; hence, HVAC systems are representative only. In addition, Vasari is considered good at simple representations of wind and shading effects but is not a true representation the actual conditions. Hence, it is useful for confirming or rejecting of initial assumptions, ideas and intuitions.

Study Type	Frequency	Vasari (DOE 2.1)	DB Arch. Pack (EP)	IES ToolKit
Building Geometry	Common	YES	YES	YES
Orientation	Fairly Common	YES	YES	YES
Site Placement (shading, wind)	Common	YES	YES	YES
Glazing/WWR	Very Common	YES	YES	YES
Shading	Very Common	YES	YES	YES
Opaque Wall Performance	Very Common	YES	YES	YES
Program Flow (energy programming)	Rare, but useful	YES	YES	?
Solar Radiation (exterior)	Fairly Common	YES	YES	YES
Daylighting	Fairly Common	NO	YES	SIMPLE
Natural Ventilation Potential	Fairly Common	NO	YES	SIMPLE

Per User Cost:		$0	$1600	$400

Table 7.2.2: Conceptual design usages comparison

The following Table 7.2 (Courtesy of Autodesk) shows the study types that can be performed and its frequency of use and the cost in a comparison with other ways of conducting conceptual studies. A lot of different studies can be performed for litterally no cost changes or schedule implication by using Project vasari especially that this would be used by the architects in the early design stages where it would be part of the designing process.

7.2.2 Example of possible design changes and possibilities:

There are many options to consider in the predesigning stages, such as what are the effects of changing the building footprint or geometry? How will it effect the energy usage? Or how would changing the orientation of the building affect the model? Building type or usage? Or the effect of surrounding buildings? Window placement? Effects of shading or glazing performance? And so much more. Two design changes would be explored in this analysis along with the effects of each on the energy model, keeping in mind that it produces comparative information and not absolute. But before that, the process of using project vasari and creating the model would be discussed.

7.3 Energy Model:

The purpose of working with an energy concept model is to be able to study the current energy consumption of the areas and systems within the building. The more detailed the model and the information entered into the program, the more accurate the energy model would be. This will enable the user to see the current energy model and make changes according to the goals and strategies of the owner. After specific modification to the systems have been made according to the interest and research of the user, the energy model analysis would be conducted again to see the difference that changes to the conceptual model and whether these changes are going in the directions and desires of the owner or designer. The energy model analysis tool is designed to be used many times from the initial model and as the design is updated accordingly to compare different design changes that occurred or is proposed.

As mentioned earlier, the energy used from this project is very high; hence, an energy model would be very beneficial to the design of the plant expansion since it will enable us to understand many different things about the current model which would help affect the design in the early design stages. After understanding the current performance of the building, modifications in the design can be conducted and then imported once again into Project Vasari. With that being done, comparison of the previous performance next to the new performance will provide valuable information regarding the feasibility of the new change in addition to a sense of direction on whether the information produced from the energy model is closer to the goals or further away.

The Energy model does its calculations based on two main aspects: the building model imported into *Project Vasari*, which is how the current building systems information is entered and its level of detail in the model; and the energy settings in the program, which is where specific information is asked for by the program to identify the type of building, location settings and so on.

For this Analysis, a model was created with a low level of detail because the main goal of this analysis is to be able to show the effects and benefits of an energy model for this program and how small design changes can affect the building performance which will enable the evaluation of that design change on whether it is a step closer or further away from the targeted goals.

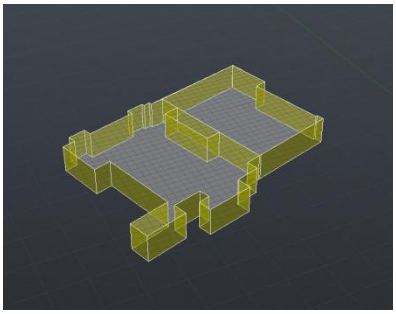


Figure 7.4: Conceptual Model of the West Fuala

In addition to the energy usage information that would be produced and compared after design changes are conducted; the energy analysis produced a large variety of information that can further the building performance. A few examples of such information would be Renewable Energy potential, Wind Rose, Weather Averages and much more which can be seen in Appendix 7. This information would not be explored in this analysis although it is undeniable that they are very beneficial and can be utilized to improve and enhance the design.

7.4 Typical process to conduct the Analysis:

Regardless of the how the conceptual mass was brought into Vasari, whether importing a detailed model from Revit or creating a fast conceptual mass model, the energy model can be analyzed. However, the best way to utilize the energy analysis feature is to conduct the conceptual energy analysis early in the designing stage before any detailed modeling occurs to see the difference in each design change and how it affects the energy model.

Creating and customizing the model:

The steps are as following:

1. Creating or importing the mass model that will be analyzed using the classic Autodesk tools provided in Vasari. For this analysis, the envelope of the West Fuala Plant was massed as it can be seen in the previous page.

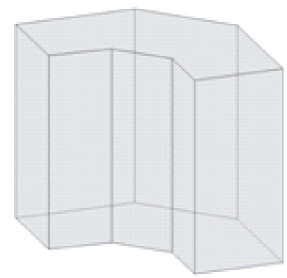


Figure 7.4.1: Mass Model

2. Adding mass floors depending on the project:

   Since the mezzanine and the basement do not cover a large area and only covers a portion of the building, the conceptual mass model of the West Fuala would be kept a 1 floor mass.

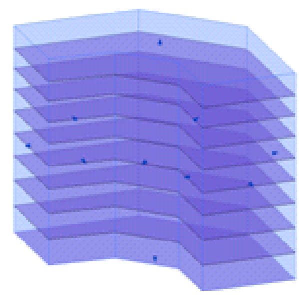


Figure 7.4.2: Adding Mass Floors

3. Creating the Energy model:

   Opening the energy settings and inputting the required information from building type (Manufacturing), Location of the project (Harrisburg, PA) and allow the creation of Energy model.

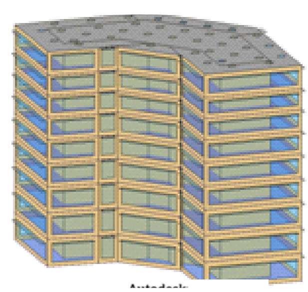


Figure 7.4.3: Energy Model

4. Review the analysis result after running the analysis.

   The study has been performed using these generic settings and it can be found in appendix 7. After more design changes occur, the energy model would be run a gain and compared to see the differences that occur and how it affects the energy model.

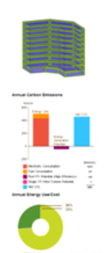


Figure7.4.4: Energy Model Results

7.5 Solar Analysis:

7.5.1 Solar Studies:

This analysis will explore natural light and shadows on the building and site. The benefit of showing the effects of natural light and shadows on the building is that it provides information that can help support effective passive solar design. It helps visualize how shadows from the surrounding environment, such as terrain and buildings, affect the site and where natural light penetrates the building at many different time and date variations throughout the day and year.

The information that will be taken from this analysis would be used to modify or enhance the design from a solar perspective, with relation to solar path design which affects the lighting of the building and solar radiation which will affect the heat produced by the solar radiation and how understanding this can alter the design to reach a better one.

As a result of information provided through the location, the effects of light and shadows can be clearly seen and easily manipulated through the use of the Sun Path is displayed as it can be seen in Figure 7.5.1 & 7.5.2 below which shows the location of the sun and its effects on the building at 06:55 PM on July 11th, 2012.

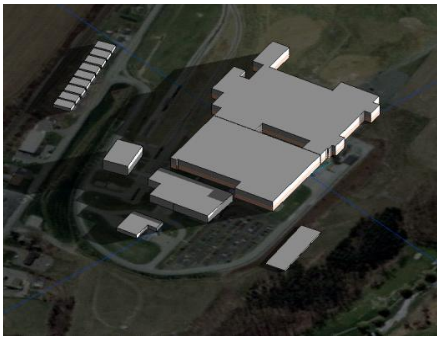


Figure 7.5.1: July 11th, 2012

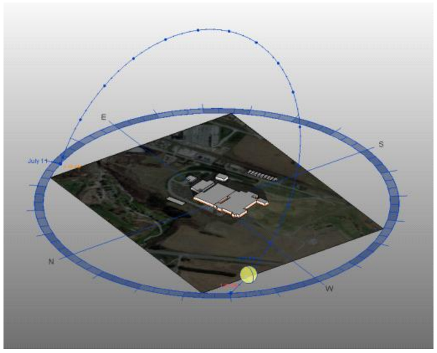


Figure 7.5.2: July 11th, 2012

Figures 7.5.3 & 7.5.4 shows the impact of the sun at 09:15 AM at November 14th, 2012.

Figure 7.5.3: Nov 14th, 2012

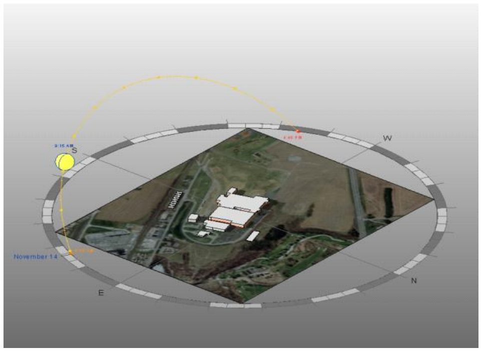


Figure 7.5.4: Nov 14th, 2012

7.5.2 Ecotect Solar Radiation:

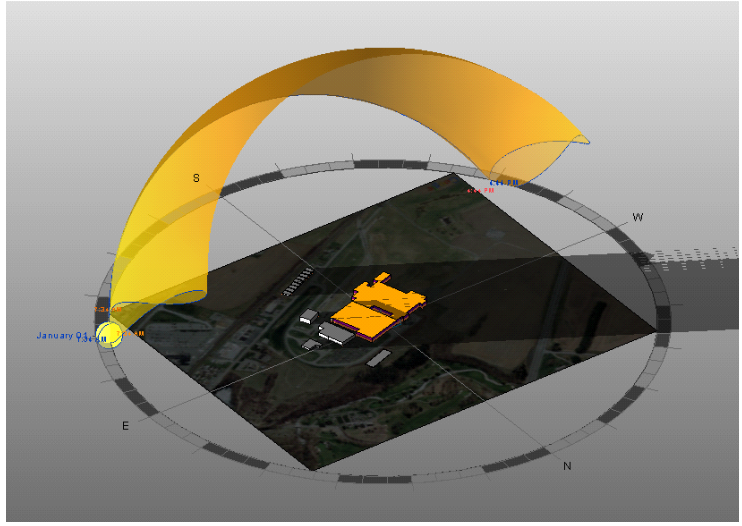


Figure 7.5.2.1: Ecotect Solar Radiation

In order to design for sustainability, many analyses have to be conducted along with an understanding on radiation on a building façade. The solar radiation analysis studies the incident solar radiation on the building. This feature too has many levels of detail where it can take into account the shading effects from nearby objects, such as vegetation and surrounding buildings in an urban setting. The end result would be figuring out the best ways to maximize solar gain by considering the effects of shadows and seasonal variations in solar radiation. For sustainability, solar radiation analysis be conducted from very early in the design process and repeated as needed as the form and design changes and evolves.

This feature requires entering some information to perform the analysis. First off, selecting the mass faces to be analyzed. In this case, only the plant will be selected without the surrounding buildings. Afterwards, the time frame and dates from which to conduct the solar radiation analysis will have to be entered. In this thesis, we will explore the solar radiation effects accumulated over an entire year on the building mass from 1st of January 2012 – 2013.

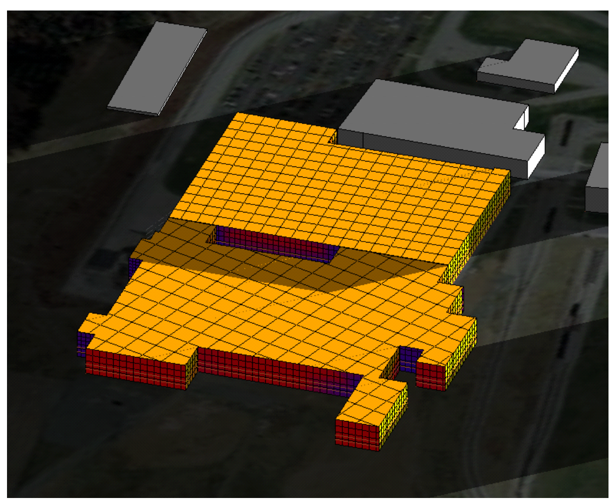


Figure 7.5.2.2: Cumulative Solar Radiation

Visual feedback is produced in two styles which can be seen in images 7.5.2.2 to the right with yellow representing high solar radiation at one end of the spectrum and blue representing low solar radiation on the other side of the spectrum. Nominal results can also be exported for other studies.

The information produced by this analysis can be used in many different ways to affect the design of the building. It can be used to quantify the difference between the incident solar radiation that occurs on the different areas and floors which would provide an understanding the importance of glazing for day lighting and solar hear gain of the building.

7.6 Application of Solar Analysis to the energy model:

After the solar analysis has been conducted, simple changes will be done using the information generated onto the conceptual model. In order to see and understand how this design changes affects the energy use of the building.

7.6.1 Design change 1: Changing the percentage glazing of the building.

Glass is one of the most important materials using in the building construction industry. It has been used for many years to allow daylight into the building while providing weather protection. Only until the 1950's that glass became widely available through economical mass production in which it suddenly became vastly used for the majority of new windows, curtain walls and skylights. Glass and glazing is a very important factor when assessing the overall building's thermal performance. The thermal performance of insulating glazing depends mainly on the on the solar heat transmittance through the glazing, the reflectance of the glazing, the width of the air space, and the material and configuration of the space around the perimeter of the unit.

Using the Energy model, an analysis would be conducted on the building to see how the percentage of glazing on the building would affect the energy use and the differences that occur. After investigating the building exterior from the drawings provided, it can be safely assumed that the building currently has an overall exterior glazing of around 20%. The energy analysis would be performed for 20% glazing on the building; after the results are ready, the analysis would be conducted once again with 10% glazing on the building.

One of the things to keep in mind when performing such analysis is that Project Vasari accounts for solar radiation depending on the time frame of the analysis to be performed; however, it does not account for solar lighting. This has to be noted when comparing the two reports to understand what systems were affected and calculated by the energy model and what was not accounted for.

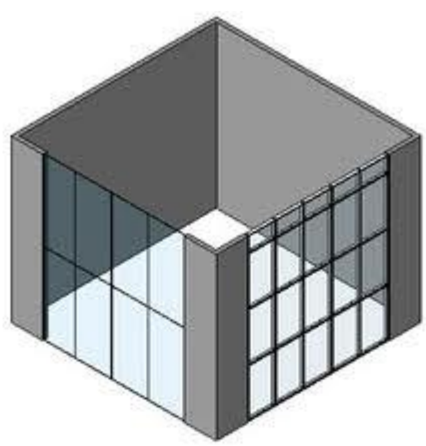


Figure 7.6.1.1: Glazing Example

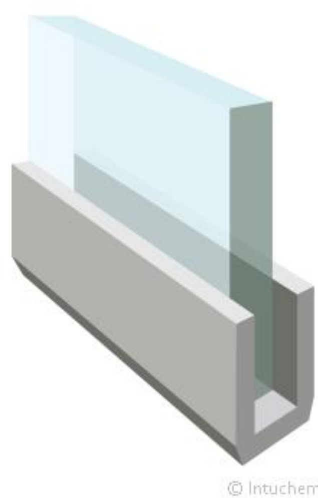


Figure 7.6.1.2: Glazing Example

7.6.2 Reading and understanding the report:

After comparing the energy reports of both options, there are many factors that have changed which affected the energy model. All the initial factors of the building such as, building area, average lighting power, electrical cost, have been maintained the same in order to have a more accurate understanding of the difference that occurred on the energy model by this change only.

Building Performance Factors

Location:	Hershey, PA, USA	Location:	Hershey, PA, USA
Weather Station:	53158	Weather Station:	53158
Outdoor Temperature:	Max: 82°F/Min: -10°F	Outdoor Temperature:	Max: 82°F/Min: -10°F
Floor Area:	277,954 sf	Floor Area:	277,954 sf
Exterior Wall Area:	166,657 sf	Exterior Wall Area:	166,657 sf
Average Lighting Power:	1.30 W / ft²	Average Lighting Power:	1.30 W / ft²
People:	646 people	People:	646 people
Exterior Window Ratio:	0.20	Exterior Window Ratio:	0.10
Electrical Cost:	$0.09 / kWh	Electrical Cost:	$0.09 / kWh
Fuel Cost:	$1.03 / Therm	Fuel Cost:	$1.03 / Therm

Energy Use Intensity

Electricity EUI:	16 kWh / sf / yr	Electricity EUI:	15 kWh / sf / yr
Fuel EUI:	26 kBtu / sf / yr	Fuel EUI:	20 kBtu / sf / yr
Total EUI:	80 kBtu / sf / yr	Total EUI:	72 kBtu / sf / yr

Life Cycle Energy

Life Cycle Electricity Use:	133,478,310 kWh	Life Cycle Electricity Use:	127,225,680 kWh
Life Cycle Fuel Use:	2,140,019 Therms	Life Cycle Fuel Use:	1,682,410 Therms
Life Cycle Energy Cost:	$6,680,366	Life Cycle Energy Cost:	$6,201,082
*30-year life and 6.1% discount rate for costs		*30-year life and 6.1% discount rate for costs	

Figure 7.6.2.1: Energy Report Comparison

It can be seen in the energy report that changing the glazing from 20% to 10% directly affects many things. The first thing that will be noticed is that the Energy Use intensity of the building has decreased from 80 to 72 kBtu per Square foot per year. In addition, the Life Cycle Energy use of the building has also decreased; 2,140,019 Therms to 1,682,410 Therms for the Fuel use and 133,478 MWh to 127,225 MWh for the Electric Use for 30 years.

A better form of comparison would be comparing the Annual Energy use of both systems: Simply reducing the glazing by 10% would reduce the overall energy use of the building. The electric system usage was reduced from 4,449 MWh to 4,241 MWh which is a good reduction while the fuel energy usage was decreased from 71,333 Therms to 55,080 Therms.

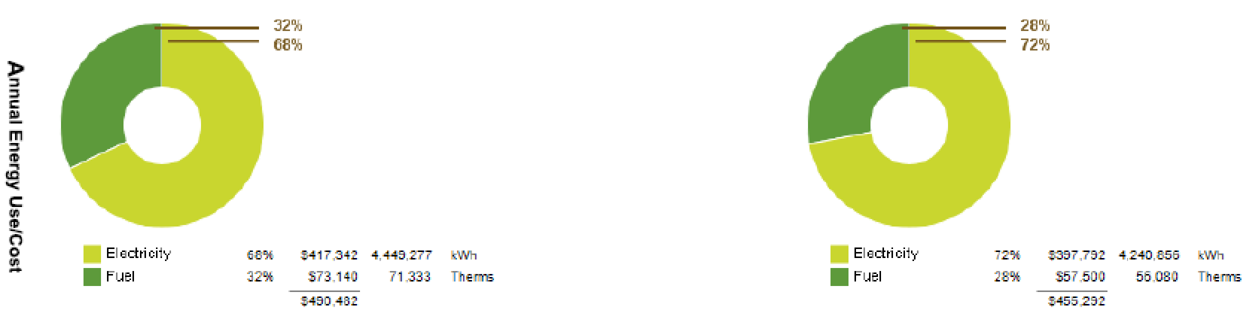


Figure 7.6.2.2: Energy Report Comparison

The second pie chart which represents the Energy use of Fuel systems specifically shows a better breakdown of what happened. Two systems were accounted for which use fuel as an energy form: Domestic hot Water and the HVAC system. Domestic hot water usage did not change since that is independent of the amount of glazing on the building, but an increase in glazing will increase the amount of heat entering via solar radiation; and for that reason, the decrease in the percentage of glazing used reduced the cooling load of the building which can be seen by the reduced amount of energy required by the HVAC system to sustain the same conditions.

Figure 7.6.2.3: Energy Report Comparison

The third Pie chart shows the energy use of the electrical systems which breaks down into three categories: HVAC, Lighting and Misc. Equipment. In this scenario, the overall energy usage of the electrical systems was reduced once again, but this time the only factor that was affected was the HVAC system. The norm would be that the lighting electric usage would be affected since the amount of glazing on the building directly affects the amount of lighting entering the building which is the oldest form of interior lighting; however, from a solar perspective, project Vasari accounts for solar heat radiation but not solar lighting. The change in glazing would be very insignificant from a lighting perspective since it is a 24/7 facility; Changing the glazing from 20% to 10% would not change the lighting methods of the building nor will it change the overall lighting usage. Hence, this change will also further reduce the heating load which is a much bigger factor that affects the bills than reducing the solar lighting penetrating the building.

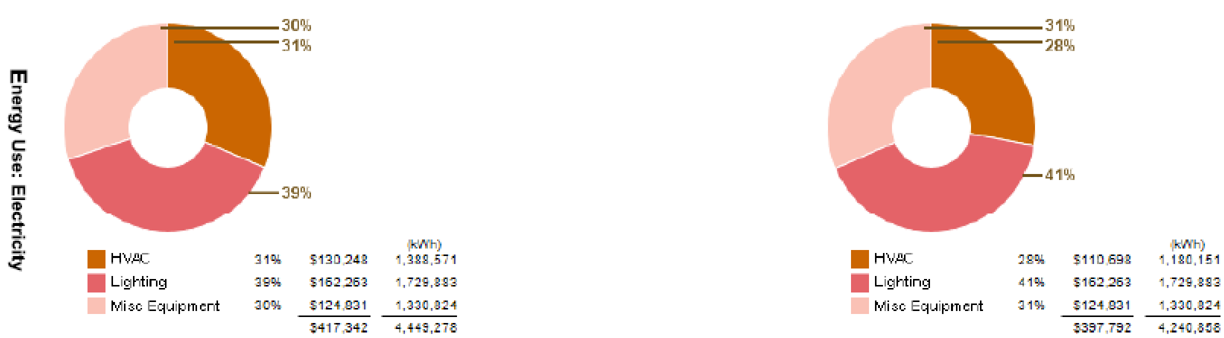


Figure 7.6.2.4: Energy Report Comparison

After reading and comparing both reports, it can be seen that changing the glazing of the building will reduce the energy usage of the electrical systems by 4.6 % annually and the Fuel using systems by around 22.78%. The reason why the Fuel energy usage has decreased more than the electric energy usage is because the heat energy produced by the building to is from assumed to be using fuel consuming systems and not electric heating systems.

From a monetary perspective, the cost of the electric systems was reduced from $417,342 to $397,792 annually turn outs to be $19,550 annually. In addition, the annual fuel cost would be reduced from $73,140 to $55,500 which is $17,640. From this analysis we cans see that by simply reducing the glazing from 20% to 10%, the accumulated annual net saving would sum up to around $37,190 per year; around 7.17 % of the annual electric bill.

7.6.3 Design Change #2: Effect of Shading the glazing on the energy model:

The second design change that will be explored would be adding shading to the building's glazing to see how this affects the energy model and whether it would be a good idea that will produce energy usage cuts or added cost with little to no difference.

The energy model will be analyzed and run for 10% glazing with no shading and then after adding shading to see how this change by itself would affect the energy use.

Comparatively, the comparison after this design change does not a huge difference in the energy usage. According to the energy report, the Energy use Intensity of the building did not change at all. As a start, it can be seen that this design change is not promising.

The Pie charts which breakdown the energy usage in more details shows minor changes: the electric energy usage had a very slight decrease after incorporating shading; however, the fuel energy usage did not decrease at all as it can be seen in the Fuel Energy Use Pie Chart.

After reading and comparing both reports, it can be understood that shading the glazing will produce minor reduction in energy usage. When compared the energy usage savings by the cost of shading the glazing, we can deduce that the energy usage will only be affect in a very minor way; the overall energy cost annually will be reduced from $455,292 to $452,967 which is a net savings of $2,325, around 0.5% of the bill.

Since study is about early conceptual energy modeling for early design decisions, showing the purpose and benefits of this analysis would be by showing how better early designing could produce energy utility cuts which is the main purpose of energy modeling. For that reason, the cost of construction and substitution of the glazing and shading by building material will not be explored even though it can be clearly understood that creating a building with a reduced energy usage with reduced annual costs will eventually offset the cost of this switch.
Note: The report comparison can be found in Appendix 7

7.6.4 Other factors to keep in mind:

Considering that the conceptual model was a rough mass model and the fact that not a lot of detailed information was entered into the program to perform the energy model analysis, the energy report does not reflect the exact usage of the West Fuala Plant. However, it can be seen from the report that it does provide valuable information from the perspective of understanding how a design change affect the entire building's energy usage.

From this analysis we can assume that reducing the glazing would always reduce the load, so one would request reducing the glazing to 0% in order to achieve an even more reduced energy bill; however, the case here is different since this is a 24/7 manufacturing facility. Normally, in other commercial or residential projects, lighting is a very important factor especially that this affects the performance and comfort environment of the residents and reduces the lighting bill, but that is not the case since this building continues to run all day and night.

Utilizing day-lighting as a substitute to lighting will inevitably reduce the lighting energy usage of a building, but to a building with this function and size, increasing the glazing and/or adding skylights would greatly increase the energy usage of the building according (See Appendix 123 – Adding skylight) which would not be recommended. This is mainly because each area in the building has a specific lighting and heat requirements that have to maintained; from that perspective, increasing glazing or sky lighting would require more energy and effort to maintain each area in its thermal zone; hence, only for this project does reducing glazing and sky lighting would reduce the overall energy usage and energy cost.

7.6.5 Recommendation for the design changes:

Looking and interpreting from the reports that were produced according to the design changes, reducing the glazing of the building would produce utility energy cuts by around 7.1% annually. The percentages will be used as a basis for approving or rejecting the analysis instead of the actual dollar values. They provide a better argument for the amount of savings that would be produced since the information from project Vasari are comparative and are not absolute; nevertheless, it is a very good representation of the changes that occur and direction of the cost changes. For that reason, it is clear from the report that reducing the glazing produces annual energy bill cuts which is very beneficial. However, the effect of shading did not produce significant changes or energy cuts; so we can understand that this design change is not significant. For that reason, I do not recommend utilizing the basic effects of shading unless a more detailed method of shading proves to produce energy usage cuts or savings.

7.7 Recommendation for Conceptual Energy modeling for early design decisions

This point of this analysis is to show how effective and beneficial Vasari's Conceptual Energy Analysis tool is to the design of the West Fuala Expansion or any other building that is using Building Information Modeling. For that reason, a simplified model was used alongside generic settings to generate the energy model and how small changes to the design can impact the energy model and eventually the design decision making process.

As we have seen earlier in this analysis, by simply exploring the effect of reducing the glazing in the building, the designers have the possibility of reducing the energy usage of the building and cut the energy bill by up to 7%. By utilizing conceptual energy modeling for early design stages and stacking the benefits through the many options to be explored, the result of energy usage cuts and cost savings is assured. In addition, the use of this program in this way has no cost since its part of the early design process by the designer/ architect and does not affect the building construction schedule.

It is highly recommended that the designers explore how an energy model can improve and enhance the design of this project. If this tool is used effectively and accurately especially by comparing how design changes affect the energy use of the building, then it is undeniable that the end result would be monetary savings through the principle of energy savings in addition to reaching a more sustainable greener building through utilizing energy reduction and energy saving concepts.

8.0 Analysis 2: Feasibility of Incorporating Photovoltaic Systems:

8.0 Problem Identification:

The main reason behind developing this idea was that this facility consumes major quantities of energy in order to operate the building itself as a structure. In addition, there is the operating cost of the process equipment that is housed in this facility which will be producing the sellable goods. Those two separate systems will all together consume major amounts of energy throughout the life of this building.

Moreover, initially the project team was targeting achieving a LEED certification for this facility. However, since the LEED rating system does include the operating cost of a facility, the facility will not be able to achieve a LEED certification as a result of the extensive major amounts of energy that will be consumed during the plants' operation; Hence, the idea of the solar Photovoltaic panels.

8.0.1 Goal:

Even though a LEED certification would still not be possible; the idea of incorporating a solar photovoltaic system would help reduce the electric consumption by a portion of the total amount. The analysis would take into consideration the cost savings of energy produced and the payback period of this system. The final outcome of this analysis is determining the feasibility of incorporating a solar photovoltaic system into the West Fuala Plant Expansion facility.

8.0.2 Procedure:

- Analyze the cost of Photovoltaic This will include:
  - Immediate actual cost of system
  - Long term cost of system
  - Construction cost of system
    - Research the most developed photovoltaic technology and see which would be the best fit for this specific project. This would include:
      - power outage
      - Manufacturer
      - Cost
      - warranties

- Conduct a solar study on the West expansion in order to measure and analyze the amount of solar energy that could be harvested and collected to produce the electrical energy necessary to power a small portion of the entire facility (for instance use the energy to light the electrical lighting fixtures).
    - Study optimum angles of solar energy
    - Study directions of solar energy for the photovoltaic panels.
    - The amount of energy that can be generated over a given area of the roof
    - Study the best location to place the PV panels on the building to harvest the maximum energy possible
- Study the best way to connect the PV system to the current electrical system to be used in the facility (lighting, ventilation… etc.)
- Develop a brief cost analysis determining the financial benefits and the payback period.

8.0.3 Possible Resources:

- Previous projects with similar intentions
- Manufacturers of Solar Photovoltaic Panels
- PSU AE faculty
- Turner representative
- Engineering Library
- Online resources

8.0.4 Projected outcome:

This analysis will comprehensively investigate the practicality of incorporating PV panels to generate electricity. The anticipated outcome of this analysis would be that the PV panels would not be able to generate all energy required to operate the process equipment or the operational cost of the building itself. However, it is anticipated that it would be able to cover a fraction of the expenses of the building systems (not the process equipment) which would help to reduce the cost and the load on the main electrical systems being utilized to power and operate the facility. In addition, it is expected that the financial analysis will show that this system would be financially affordable and worth the payback period.

8.1 Background information

The West Fuala Plant Expansion is a huge food processing and packaging industrial building and a major supplier along with other Fuala plants that supply the world with the goods and products that Fuala supply. With that being said, the importance of maintaining continuous production lines 24 hours a day, 7 days a week cannot be stress enough since it is a global and national supplier which is the intended purpose of this plant along with running this plant 24/7 as working hours of this plant.

The general cost of the building envelope is average compared to other similar projects. However, the process cost of running the plant nearly every day and every hour of every year, except in limited special circumstances such as cleaning the equipment, in terms of electric and mechanical heat is very high which was the main reason for discontinuing the pursuance of a LEED certification for this project. Along with high usage costs comes a huge bill. This is where this analysis comes into place; reducing load from the grid and providing energy savings through engineering economics.

Since reducing the load is not possible as that is dependent on the process equipment, their working loads and times. Hence, the only other way to reduce the cost would be generating energy to reduce the demand on energy which will reduce the bill. This is where Photovoltaic panels come into place.

Photovoltaic panels are known to be 100% beneficial product since it will always yield a payback period through the laws of economics and engineering. However, there are many other reasons as to why it is a very good idea to incorporate photovoltaic panels into any project and specifically this project.

First off, they are being produced cheaper and more efficient than ever at this time. All suppliers have offers on their products, in addition to transportation, installation and operation being facilitated. Moreover, with federal benefits and support along with state incentives, this money saving green technology's demand has greatly increased along with increased research to develop and improve it even more.

Secondly, this system would prove very beneficial for this project for the following reasons, but are not limited to it:

1. Available unused open space, which allows the PV panels to be placed on the huge room space available or on grade anywhere with no limit to the amount of PV panels placed is so desired
2. The potential to reduce power from grid, which allows major energy savings proportional to the number of PV panels used to generate electricity
3. Fuala plants have had a span life of over 100 years and are still operating. Hence, providing an energy solution that can reduce energy usage from the grid and save

money through time would be very economical especially for the expected span life of a building with a huge energy consumption rate.

4. Isolation of Site, since the project is far away from nearby structures where there will be nothing blocking sun rays from reaching the panels which adds to efficiency of generating electricity, reduces error in installation from the perspective of tilt accuracy and inner-row shading, provides the option to place an large amount of PV panels as desired, freedom to make changes to project since it is not limited to a specific place and is located nearby on grade (and not on the roof, although that is a very feasible option)
5. Attainting a LEED certification was not possible for this project as mentioned earlier as a result of the high usage of energy from the process equipment used in this plant. Nevertheless, not receiving a LEED certificate does not mean halting the goal of reducing the carbon emission and reaching for greener solutions. Such solutions, even if they were minor, are steps to reach a greener world with less carbon emission. Hopefully, someday there will be a certification for industrial buildings to acknowledge their efforts for a cleaner environment in which this project would be already qualified for.

8.1.1 Case Study:

Even though this analysis only studies powering a small fraction for many reasons; many people would be skeptic with regard to powering a plant with photovoltaic electric energy. There are two main reasons:

The first would be the energy usage of industrial building, indeed it is a high energy usage manufacturing plant, but it is inevitable that using solar energy will always yield a payback period since it is a sustainable clean form of energy than is self-generated. So practically, the more PV panels are used, the more benefits there will be in the long run. However, the only set back would be the large capital investment that should be available which is not the case with the owner of Fuala since cost is a very important factor in the decision making and the idea of generating renewable energy on site was ruled out.

The second reason would be that PV panels would be an old technology soon since the next form of clean energy would be using nuclear power. Indeed nuclear power maybe the next form of energy, but self-generation of nuclear energy is not possible in addition to the time it will take to develop the technology.

PV panels are growing rapidly to a total global capacity of 67,400 MW by the end of 2011, 0.5% of worldwide electric demand. The next step in PVs is massive electric generation of large systems which have been already established in many areas around the globe. The images below are massive electric generation plants with system sizes ranging from 2.5 MWp – 11.7 MWp.

Image 8.1.1: Location: Thuringia

Image 8.1.2: Location: Canada

Image 8.1.4: Location: Slovakia

Image 8.1.3: Location: Brandenburg

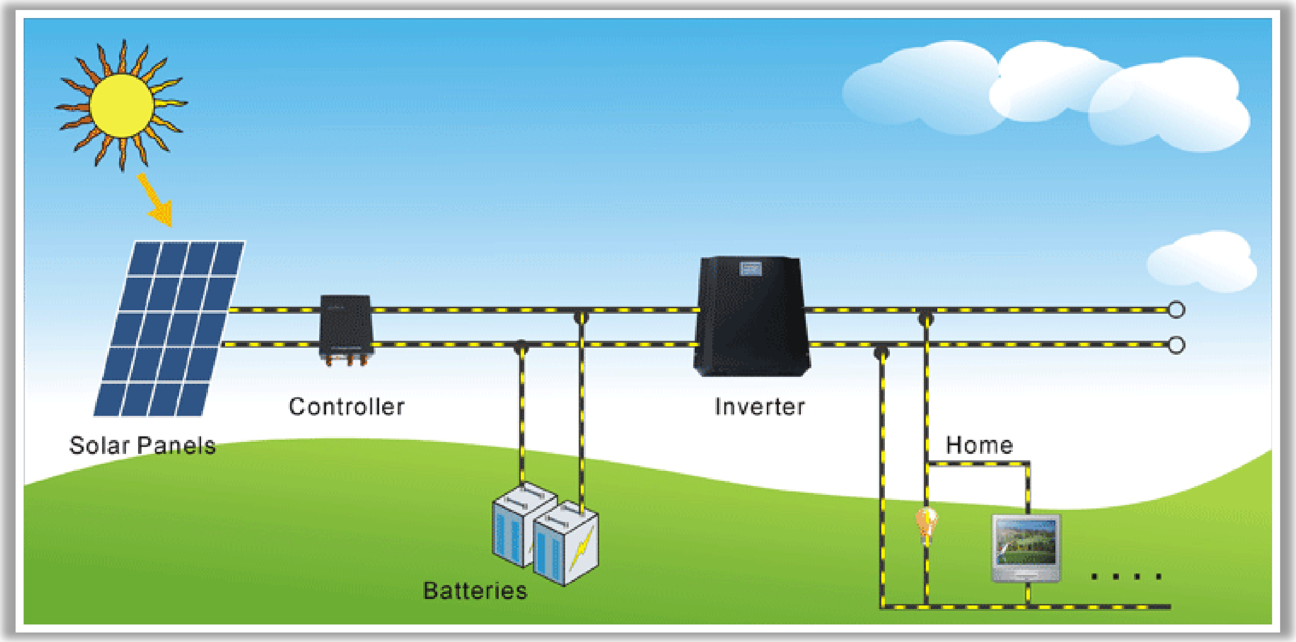
The most amazing massive electric generation project using renewable energy including PV panels is Masdar City, United Arab Emirates; a city which will rely entirely on solar energy and other renewable energy sources with a sustainable, zero-carbon, zero-waste ecology. As of June 2009, it has activated its 10MW solar PV power plant which was the first step before construction of the city; the reason as to use PV electricity for the construction process. An entire city powered as such would have major benefits from a reduced cost and future sustainability; from that perspective, any plant or any building should invest in sustainable energy to attain its benefits especially free energy generation.

Image 8.1.5: UAE Map with Masdar City

image 8.1.6: Masdar City PV

8.2 How a PV system works and connects to the grid:

The system that would be used to connect the PV panels to the building's electrical system would be an Off Grid remote solar power system. Such systems will require very little maintenance simply because the systems will be installed in place and will not be moving. Failure is very rare with PV systems however efficiency may be reduced over a long period of time but does not exceed 10% of power output through a 10 year limited warranty and 20% of power output through 25 years.



The main components of an off grid solar power systems are the following:

- Solar Panels: Those are a solar-electric system's defining component where sun rays are used to generate a direct current electricity through the photovoltaic effect. PV panels are rated using watts based on the maximum power they can produce under ideal sun and temperature conditions.
- Solar Panel Mounting Frames and kits: The Array Mounting Tack provides a secure platform to anchor the PV panels which prevents their movement to maintain inner-row shading along with the tilt orientation. Panels can be mounted on a rooftop, on top of a steel pole or at ground level.
- Controller: The main function of this device is to protect the battery bank from overcharging since batteries are expensive and are very strict about how they work and perform. The controller interrupts the flow of electricity from the PV panels when the

battery bank is fully charged. Avoiding overcharging or undercharging maximizes their lifespan.

- Battery bank: This is where the energy is stored when electricity is generated from the PV panels which allow the use of stored energy at any time even when there is no electricity generated from the panels. Lead-acid batteries are the most common batteries used in solar-electric systems.
- Power Inverter: The panels produce a Direct Current when most electrical building systems use an Alternating Current. This is where the inverters come in place and invert between the currents. They synchronize the electricity they produce with the grid utility grade AC electricity allowing the system to feed solar-made electricity to the utility grade.
- System meter: They are optional and are not required to operate the system; however, they are very useful as they measure and display several different aspects of the solar-electric system’s performance and status, tracking information such as how full is the bank, how much electricity is produced by the panels or have produced and how much electricity is being used.

8.3 Electrical Systems Analysis (Breadth)

For this analysis to be successful, feasible and useful, this system should be able to provide electricity to a system or area with the goal of reducing the costs and the electric consumption from the grid while shifting towards a renewable cleaner source, in this case solar energy.

The first step to designing a solar-electric system would be by calculating the possible loads that could be covered through this system. The building as an industrial process plant consumed major amounts of electricity which cannot be cover at all through such a system

Table 8.3 below shows the end use energy consumption data for manufacturing buildings according to the U.S. Department of Energy.

Table 8.3: Manufacturing End-Use for Commonly Used Energy Sources for 2002 (Trillion Btu)	Total Fuel	Percentage	Electricity	Percentage
Total Fuel Consumption	17,670	100	3,458	100
Indirect Uses-Boiler Fuel	3,110	17.60	12	0.35
Conventional Boiler Use	*1,679*	9.50	*9*	0.26
CHP and/or Cogeneration Process	*1,443*	8.17	*4*	0.12
Direct Uses-Total Process	5,722	32.38	2,218	64.14
Process Heating	*3,595*	20.35	*343*	9.92
Direct Uses Total Non-process	1,124	6.36	514	14.86
Facility HVAC	*697*	3.94	*262*	7.58
End Use Not Reported	300	1.70	96	2.78

The information above provides an understanding of the percentage usage of each electric system in a manufacturing facility. The case with manufacturing plants is that all systems related to the manufacturing process consume large amounts of electricity. These systems are vital for running the plant as intended with no issues. The only area in a plant where there is substantially less amount of energy used would be the systems not related to the manufacturing process. In the Fuala Plant expansion, there are systems in smaller areas scattered throughout the building that have nothing to do with the manufacturing process. Area O would be the perfect example of an area of the building that does not run as an industrial building but more like a commercial through its use.

Area O is contains the recreational facilities of the plant such as cafeteria, locker rooms, shower areas, Fitness room and so on. Accumulating the overall wattage requirements of the Panel boards in area O from the electrical drawings provided, the energy requirement would be around 380 KVA.

The type of equipment used in this are: refrigerators, microwave ovens, fitness equipment receptacles, vending machines, coffee makers, office equipment, in addition to the lighting fixtures in area O mainly and few other lighting fixtures in the east parking lot and some corridors. The lighting fixtures used all over Area O are florescent lights as the rest of the entire building.

8.4 Solar analysis

The West Fuala Expansion is located in a good location which allows for minimum interruption of sun lighting reception from obstacles since it is isolated from any structures around it. In addition, there is a large amount of area on the roof or on grade which can be utilized as desired by the owner in which the panels can be anchored. Hence, there is no limitation to the number of panels placed or location of area, which are ideal conditions for the usage of solar energy and the flexibility of design and choice. In addition, the Energy Analysis in the previous section showed that utilizing solar concepts for the building may have high returns.

The next step after figuring out the loads of the systems that have a potential of yielding good results from this clean energy solution and cost reduction plan would be to perform a solar analysis for the project location and specifically building site. The purpose of this analysis would be to see if a solar-electric system would be even possible; this solely depends on the amount of sun rays that the PV panels can absorb.

Figuring out the amount of sun rays that can be collected by the photovoltaic panels depends on many factors such as but is not limited to: sun hours per day, temperature, tilt angles, orientation. The following parameters are summarized in the following ***Table 8.4.***

Table 8.4: Parameters for Solar Analysis

Project location	Abu Dhabi, PA
Latitude	N 40° 22’
Longitude	W 76° 85’
Elevation	348 ft. (106m)
Sun Hours Per Day	4.6 (Taken For Harrisburg, PA)
Optimum Orientation	South facing side
Optimum Tilt Angle	Summer: 25°15’ Winter: 55° (latitude ± 15°)

8.5 PV system manufacturers

The next step in this analysis would be comparing different Photovoltaic panels to decide which would be the best option for electric generation generally and specifically for this project. The typical method of comparison between panels would be through efficiency where electricity generated per area of panel would be the deciding factor since in most cases; the panels' only location to be anchored would be on the room of the building.

However, that is not the case for this project as the panels do not have to be mounted on the roof. On the contrary, there are many advantages to place them on grade such as:

Flexibility of installation: The panels can be installed anytime as long as the earth has been graded which usually happens earlier in the project. They can be located anywhere since there are no specific constraints to where the panels have to be placed within the plant's premises.

Ease of installation: Since the panels will be mounted on grade instead of placing them on the roof, the job can be done with much freedom and ease. This results in a minimum amount of error. In addition, amendments and modifications can be done with ease when the panels are on grade.

Visibility of panels: The norm is to place photovoltaic panels on the roof to hide them as they claim that they hinder the architectural aesthetics of the building, even though that is a personal opinion. However, this project is an industrial project where aesthetics do not matter. On the contrary, showing the panels will allow the viewers to see and acknowledge that this industrial project took a step towards a cleaner environment when that is very uncommon for industrial projects.

Since area is not a limitation, the panels will be chosen by finding out the best panels that provide electricity per price and in order to cover a good percentage of the lighting system, which is the goal of this analysis.

After contacting several manufacturers and comparing deals, "*Wholesale Solar*" located in Mt. Shasta, CA provided the best deal as they had a good deal for ordering large numbers of panels. They were one of the few to provide a solar system with 80 panels.

The panels that provide the largest amount of wattage per dollar from this manufacturer were the Astronergy 240-Watts Module. The specifications can be found in ***Table 8.5.2*** below.

Table 8.5.2: Specification of System						
Solar Sky Giddied Systems	Array Size STC / PTC *	Monthly Output based on 5 hrs. sun a day	Number of Solar Panels	Inverter	Price	Price Per Watt
Solar Sky Gridtie System 19,200 watts	19,200/17,448	up to 2,617 kWh	80 Astronergy 240-watt	2 Fronius USA IG PLUS V 10.0-1 208/240/277	$37,889	$1.92
Solar Sky Sharp Grid Tie system 18,800 watts	18,800/16,944	up to 2,542 kWh	80 Sharp ND 235 Watts	2 Fronius USA IG PLUS V 10.0-1 208/240/277	$42,110	$2.24

After contacting "Wholesale Solar" about their product, the following was noted:

- Cost of System $37,889.00 For the System
- The system includes all equipment shown in Table 8.5.3
- Transportation would be for free for a set of 10 or more.
- Labor is not included.

Table 8.5.3: Grid Tie Solar Power System
80 Astronergy 240-watt modules
2 Fronius 10,000 watt inverters
16 MC4 100' cable extensions
2 Solar Disconnect warning 2-piece label – single
2 DC Disconnect warning 2-piece label – single
1 WSS Gridtie System Wiring Diagram
2 Square D 60 amp DU222RB Safety Switch 240VAC

8.6 Layout of the PV system:

Image 8.6.1 below is a drawing though AutoCAD drawn to show the dimensions, tilt angle, spacing, and inner-row shading for each 20 Astronergy 240-watt module which will be placed in a gridtie system.

The inner-row shading distances and tilt angles can be seen below.

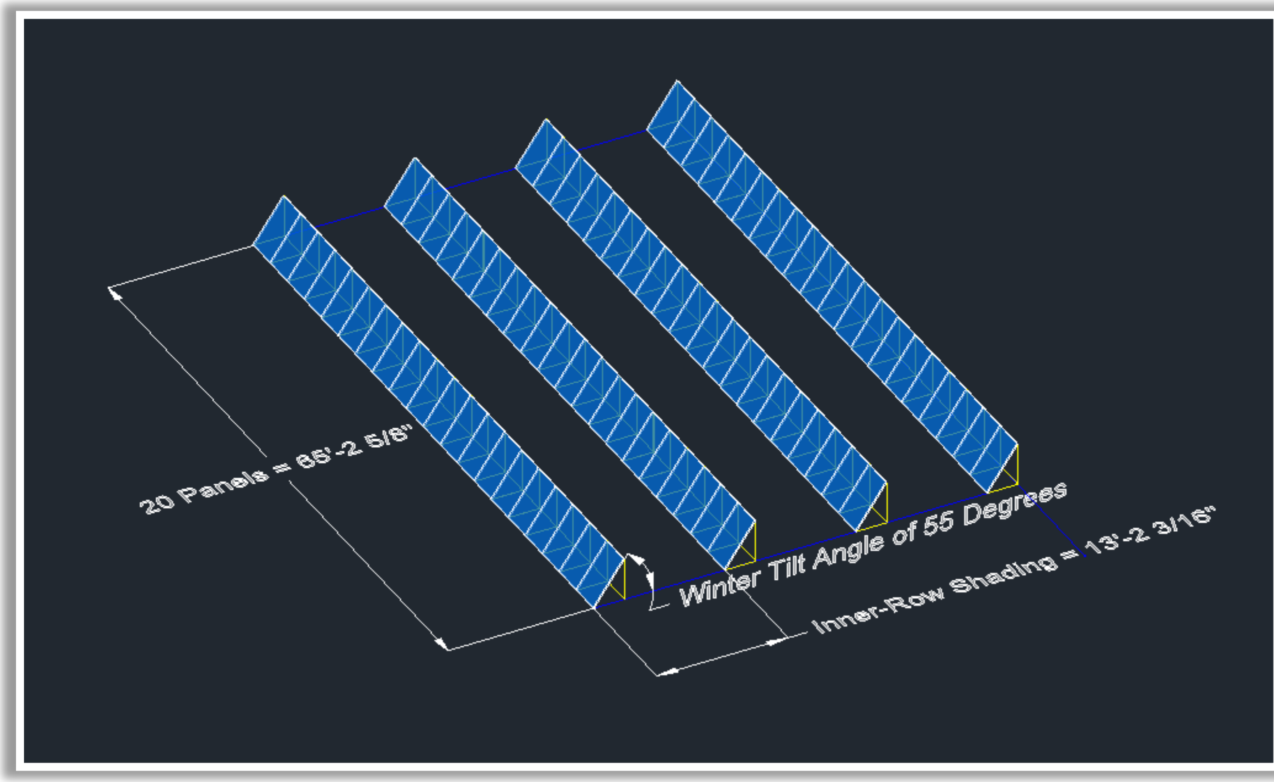


Image 8.6.1: 80 Astronergy a Gridtie

The following Image 8.6.2 shows the proposed location on where the photovoltaic panels will be placed on grade with regard to the entire site. It will be located northwest of the main building and just to the north of the parking lots. A great advantage of this layout is that the owner can place as much panels as desired to meeting their economic or environmental goal. The green rectangles are a set of 10 gridtie systems of 80 Astronergy 240-watts. The blue rectangle show the building itself. This images depicts the area of 800 panels with regard to the

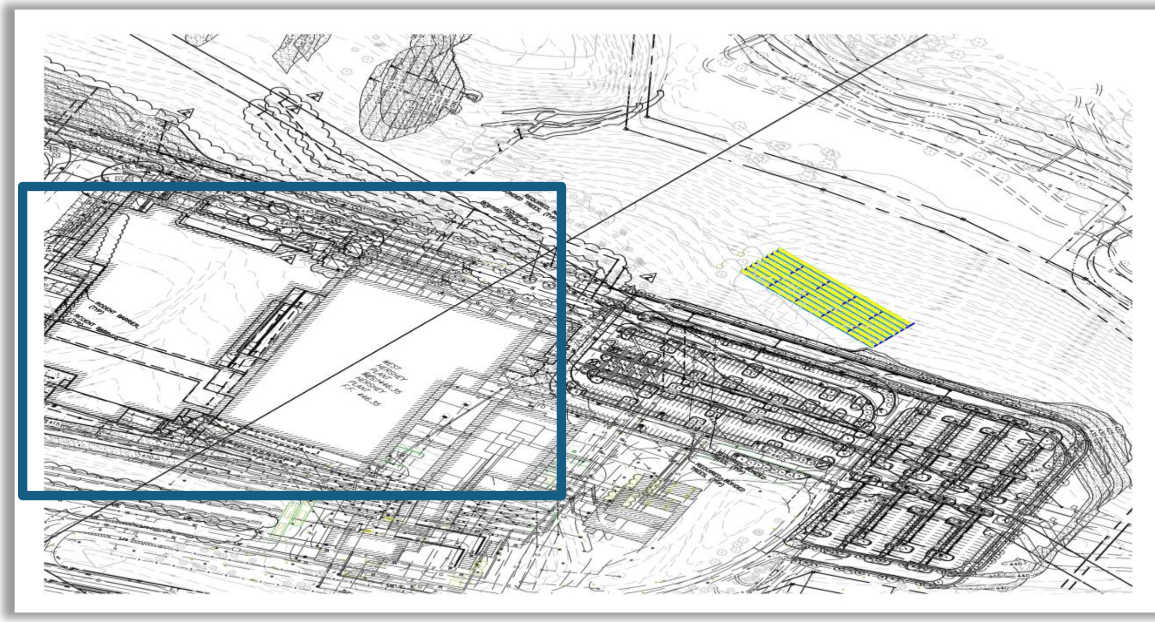


Image 8.6.2: 10 Sets of 80 Astronergy on a Site Plan

There is still the option of mounting the PV panels on the room. The following picture is a rough sketch of the panels with the dimension of the rood to provide a rough idea of the possibility of this option instead of placing them on grade.

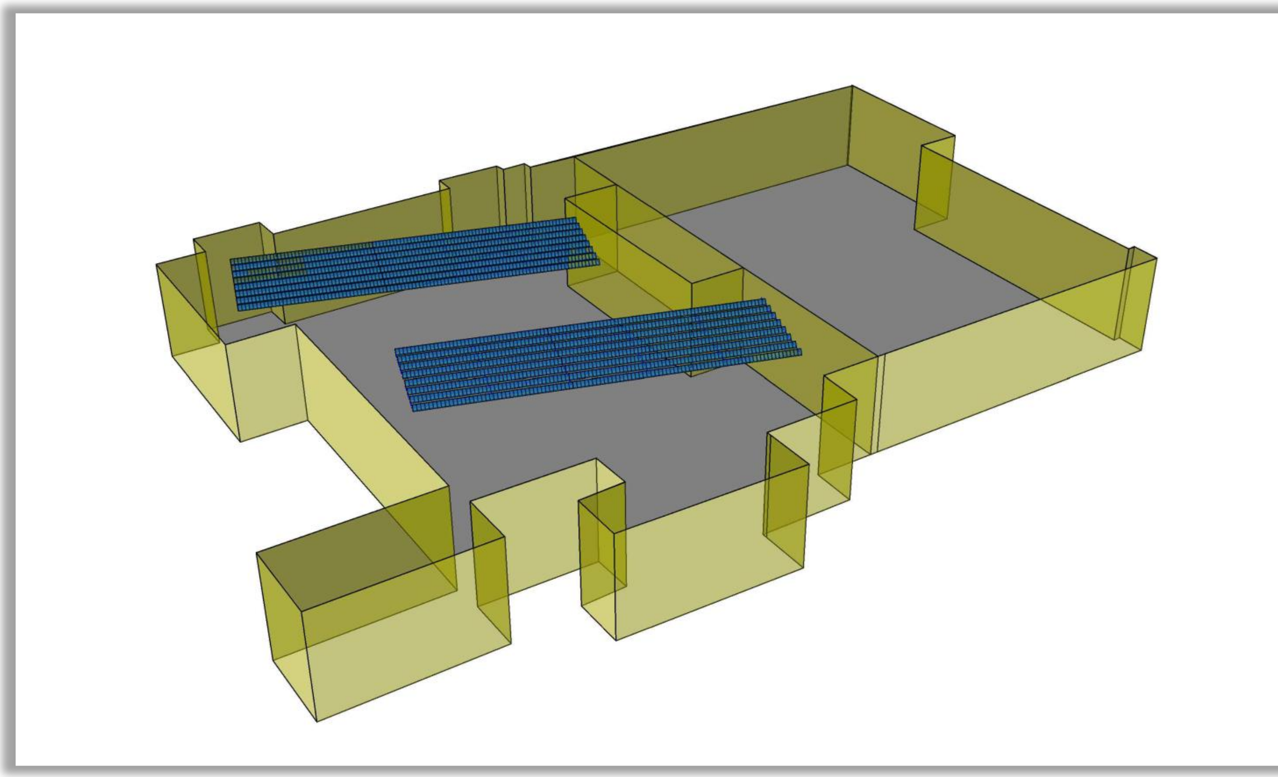


Image 8.6.3: 2 sets of Astronergy on the West Fuala

8.7 Electrical Energy Produced: (Breadth)

Calculating the electric output produced by the photovoltaic panels will follow as the next step on the analysis. The calculations will be done for 1 set of 80 Astronergy 240-watts module. This can then be interpolated to see the cost and savings if more than 1 set would be used.

8.7.1 Rough calculation:

Area O can be considered an "office building" in that it has various components that are found in office building in addition to the fact that it is on the other side of the Fuala plant and has nothing to do with the manufacturing process at all. With that being said, assuming a PF of 0.90 for the electrical systems in area O, a 380 kVA would require (380 kVA * 0.8 PF) = 304 kW of energy to power the system. And since each set of Astronergy can provide 17.448 KW of energy as seen in the specification previously; dividing the total energy required by the amount of energy produced by each set would yield the number of sets required to cover the total system. In this case 308 KW/17.448 KW = approximately 18 sets of 80 Astronergy 240-watts. This calculation provides an understanding of the ratio of panels to percentage of energy.

1 set of 80 Panels = 17.4 kW
% energy covered = (17.4kW) / (308 kW) = 5.65 %

Each set of 80 Astronergy 240-watt panels covers around 5.65 %. Hence for each added set, the percentage covered increases by 5.65. So for 10 sets, the owner would be able to cover 56.49 % which is more than half of the entire office load.

8.7.2 Detailed calculation:

To produce a better more refined comparison, the energy output must be converted from DC output to AC output since the electrical system of the building is an AC current. The National Renewable Energy Laboratory provides research and information for a lot of renewable energy projects and systems, one of them is a Photovoltaic system calculator which calculates annual AC energy produced.

The calculator required the input of the information to the right in Table 8.7.2-Station Identification and they are as followed:

- Location of building, which is was chosen to be Harrisburg for confidentiality
- DC rating of PV system, which can be found from the PV panels specifications sheet
- DC to AC Derate Factor (0.77 by default), which calculates for many factors such as wiring, soiling, age, inverters and transformer
- Array type, chosen to be fixed as is the proposed plan.
- PV Array Tilt, provided automatically through the location.
- Cost of electricity, determined from the U.S. Energy Information Administration

Table 8.7.2: *Station Identification*

Cell ID:	263372
State:	Pennsylvania
Latitude:	40.3 ° N
Longitude:	76.8 ° W
PV System Specifications	
DC Rating:	174.5 kW
DC to AC Derate Factor:	0.77
AC Rating:	134.4 kW
Array Type:	Fixed Tilt
Array Tilt:	40.3 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	14.3 ¢/kWh

System usage in KWH => 380 KVA * 0.8 (PF) = 308 KW

308 kW * (24 hrs) = 7,392 kWh per Day

7,392 kWh * (365 days) = 2,698,080 kWh used annually.

Upon entering the 'Station identification' information, the photovoltaic calculates the solar values for each month along with the AC energy produced and the energy value which can be observed in the ***Table 8.7.3*** below. The information has been processed for 10 sets of 80 Astronergy 240-watts modules.

Table 8.7.3: ENERGY PRODUCTION RESULT

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	3.13	13297	1901.47
2	3.75	14310	2046.33
3	5.03	20708	2961.24
4	5.13	19727	2820.96
5	5.42	20499	2931.36
6	5.53	19707	2818.1
7	5.32	19470	2784.21
8	5.25	19305	2760.62
9	4.93	17913	2561.56
10	4.49	17545	2508.94
11	3.27	12771	1826.25
12	2.79	11683	1670.67
Year	4.51	206937	29591.99

Table 8.7.3 shows that 10 sets of 80 Astronergy are anticipated to produce 206,937 kWh of energy with an annual savings of $29,592.

8.8 Financial Analysis:

The final step in the process is conducting a financial analysis to determine if the photovoltaic system is worth investing. Logically, any system that reduces energy required from the grid will provide savings and a payback period down the road; so the real question is, how long will the payback period take and how much savings can be harvested.

8.8.1 Detailed Calculation:

A more details calculation has to be made to determine the cost and savings over a 50 year span to understand the rate of savings along with the payback period for this system. The cost of the system will be determined in order to be able to provide a close estimate of the entire system cost.

Cost of system:

- Cost per DC-watt= $ 6.92 per Watt DC
  - The cost of the system as stated by "Wholesale Solar" = $1.92 per Watt DC
    - Cost includes all of the components in Table 8.5.3
      - 800 panels, 20 Inverters…
  - The cost of labor/installing the system = $5 per Watt DC
  - Transportation cost = $0 if more than one set of 80 is ordered
  - 174.5 kW – DC for 10 sets of 80 panels
  - **Total cost = $6.92 x 174.5 kW = $1,207,540**

Fortunately, there are many cost reductions by the government and states that can reduce the cost of the system as an incentive for people to invest in renewable forms of energy. They will be considered and calculated to see what the system cost would be after the reductions.

- Federal Tax Credit: 30% of Gross Installation
  - $ 362,262
- Pennsylvania Sunshine solar rebate program: $52,000
  - Maximum incentive: Lesser of %52,000 or 35% of installed costs
  - Eligibility requirements: 3kW minimum
- Pennsylvania Solar Renewable Energy Credit market:
  - Assuming $220 per MWh for 10 Years
  - 206,937 kWh x $0.22/kWh x 10 years = $455,261
- Total incentives = $ 869,523
- **New Net total system Cost = $338,017**

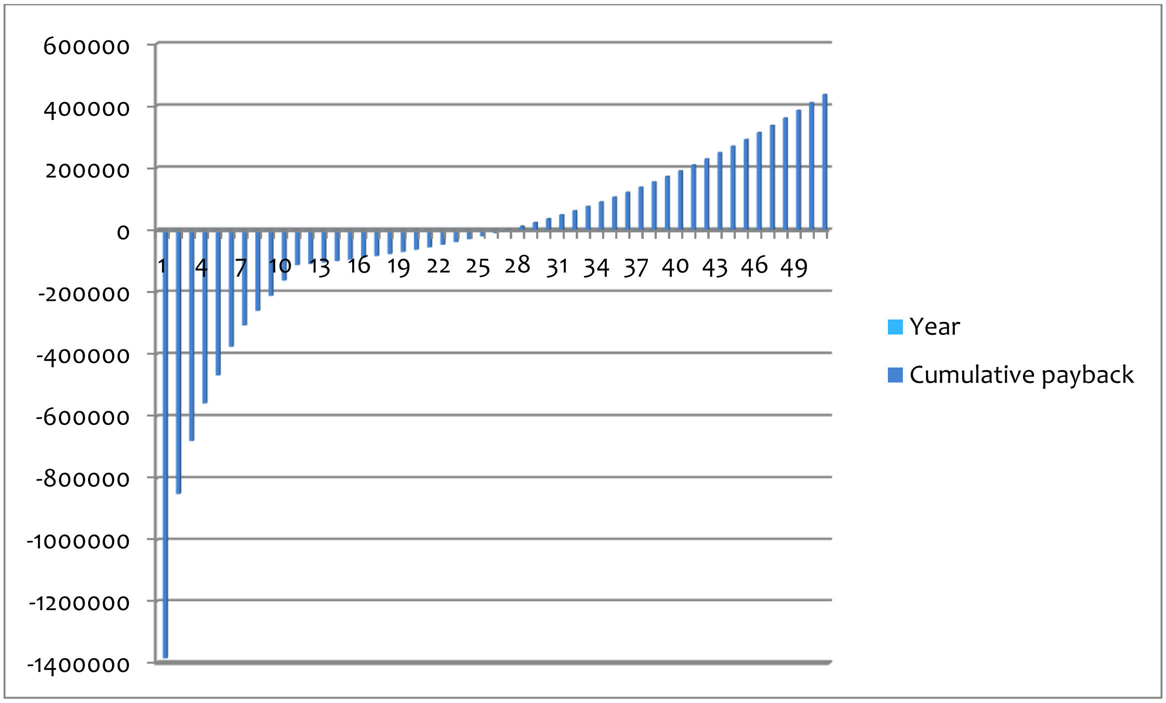
Table 8.8.1:	Description	Monetary Values ($)	COST	Assumptions
Estimated System Cost	Assumed Installation Gross Cost		$1,207,540	Assuming $6.92 per Watt DC
FINANCIAL INCENTIVES	Pennsylvania SREC Market	$ 455,261		assumes $ 220 per MWh for 10 years
	PA State SunShine Rebate	$ 52,500		
	Federal Tax Credit	$ 362,262		30% of Gross Cost at Installation
TOTAL SAVINGS		($ -869,523)		
ESTIMATED NET COST AT INSTALLATION:			$ 338,017	

The calculations in table 8.8.1 above have provided the cost of the entire system in addition to the incentives and rebates; the net system cost would be $338,017. Other than the Tax credit and the PA sunshine solar rebate; Solar Renewable Energy Certificates (SRECs) are given to owners who can guarantee that their solar energy produced does not fall short of the designed values. PA SRECs are granted on a rate of $220 per MWh produced by the photovoltaic panels.

After calculating all the costs and the incentives of installing and running the system, the final step in this financial analysis is to generate a payback period chart. System Advisor Model (SAM) is a reliable program provided by the national renewable Energy Laboratory for no cost in order to calculate the performance and financial elements of a Photovoltaic system. The numbers calculated above were entered into the program in addition to many parameters and assumptions which are the following:

- Zip Code: in which it would use the location to calculate rates in that area and other specifics. Harrisburg was used once again with a zip code of 17112
- Utility company: PPL electric utilities Corp was chosen as it serves that area.
- Electric Rate: $0.143/kWh
- Utility Annual inflation Rate: 3.78%
- Federal income Tax Rate: 28%

- State Income Tax Rate: 3.1%
- No loans
- No transportation costs
- Escalation of 2% in the production tax credit
- System degradation of 0.5%
- System Cost = $6.92 per Watt DC



8.8.2: Payback period of the System in 50 years

Graph 8.8.2 above shows a savings escalation graph. The cost of the system according to SAM was $1,385,090. It starts with the initial cost of the entire system and then ads the savings amount per year to the initial cost and accumulated it for 50 year. The first Ten years has a steeper slope than the following years which is a clear indication of the effect of SREC on the system cost. In addition, the tax credits and rebates were not included from the beginning since they are not instance and are returned with time. It can be seen clearly in the graph that payback period would be in 26 years which a good investment is considering the size of the system. In addition, it also shows the future savings value for each year after breaking even. Appendix 8 will include a cumulative cash flow table of the financial report.

8.9 Recommendation and Conclusion:

A first glance at the costs of a photovoltaic system would typically result in skepticism and the hesitation of incorporating the idea. However, conducting and researching this analysis from a solar, electrical, technological and financial perspective, the system becomes more appealing. It is actually a great investment for the West Fuala expansion for many reasons that include but is not limited to:

- Implementing a green renewable system
- Becoming one of the few industrial projects that implement green projects.
- Own an energy generating system connected to the Plant
- Ceasing the opportunity of the Tax Credits and State Rebates that exist at this time that create a major difference in short term costs and creates opportunity for more long term savings
- Installing 10 sets of 80 Astronergy 240-watt panels provides around 50% of electric energy sustainably generated.
- Payback period of 25 years
- Placed on Grade. That is, it does not impact the schedule and does not coincide with other trades. Ease and flexibility of installation.

This analysis proves that it is highly recommended that the West Fuala Expansion Plant considers investing in solar energy, specifically photovoltaic panels, as it is a great step towards renewable energy, sustainability, monetary savings and a better public image and reputation of this global supplier.

9.0 Analysis 3: Structural modification to a Precast Mezzanine

9.0 Problem Identification:

For an industrial facility, having a steel design of the structure is much easier to design and construct compared to a precast concrete structure which requires more planning, coordinating and communicating with the other engineer and designers. However, since the entire facility's structure would be constructed using concrete; and since there are major procurements of precast members for the envelope of the facility; it is an advantage to construct and design a precast mezzanine along with the rest of the building. In addition, a precast plant is favored over a steel structures plant for hygiene issue.

9.0.1 Goal:

The goal of this analysis is to redesign the structural system of the mezzanine to achieve a much easier system to construct and procure in addition to reducing the overall cost and schedule duration of the project.

9.0.2 Procedure:

- The study will be performed initially on a typical bay which would then be expanded to the entire area of the mezzanine.
- Analyze the cost of switching from steel to precast. This will include:
    - Immediate actual cost of both systems
    - Long term cost of both systems
    - Construction cost of each system
        - Equipment
        - Material
        - Machinery
        - Storage cost
        - Labor
        - Shakeout and laydown areas
        - Transportation cost of each system
        - Environmental cost – long term

- Study and compare the duration impact of both systems on the project schedule. The following factors will be included in the analysis.
    - Logistics - rearranging

    - Labor difference
    - Placing time
    - Critical path alteration
    - Efficiency of workers
- Analyze other factors of the both entire systems such as safety, logistics, and sequence and so on.

9.0.3 Possible Resources:

- Previous projects with similar intentions
- Precast system manufacturers
- Turner Projects representatives
- PSU AE faculty
- Engineering Library
- Online resources
- Steel fabrication company
- Available schedule time and estimates for structural system construction.

9.0.4 Projected outcome:

The anticipated outcome of this analysis is that the suggested precast system would have an overall advantage when compared to the current structural system. The comparison between the two systems will be with regard to the construction management portion of the systems which includes cost, schedule duration, logistics, and safety and so on.

9.1 Background information:

The envelope of the West Fuala Plant expansion was constructed and erected using Precast Concrete units ranging from 32' high Precast wall panels and 32' span Double T's for the roof, up to small 48" wide x 30" deep precast concrete beams. Most of the structure has been erected using precast concrete panel, which is a great idea since it is known to cut schedule time significantly, reduce site congestion, potential reduction in cost. There are minor areas in the building that has been constructed using other trades which worked out to be the best option for those special cases which are usually small confined spaces or corrections et cetera. However, there was only specific structure that was not precast for specific reasons. That is the steel mezzanine spanning over areas B, D, F and H.

The Steel Mezzanine is a large area constructed from Hollow Structural Steel beams and girders along with a steel column. The main reason for designing and constructing the mezzanine using steel was the communication problems that happened earlier in the design phase. The entire envelope's specifications and designs were completed and were procured; except for the mezzanine since the location and quantity of the MEP penetrations were not known until later. For that reason, an alternative steel design using HSS was chosen which does not require knowledge of penetrations.

The main reason for designing the plant using concrete in lieu of steel is that it is it better for plants, especially food processing plant, for hygienic reasons. It is easier to clean and maintain than steel, which is a priority since inspections are frequent and random. For the same reason, if the MEP penetrations were known earlier, the mezzanine would have not been a steel mezzanine as is the case now.

9.2 Redesigning the Steel Mezzanine:

9.2.1 Description of the current system:

The Mezzanine to be redesigned extends from area B with a width of 89'6" for 96 feet southwards and then from areas D, F and H with a width of 32' for 320 feet. This Analysis studies replacing the steel structures used to erect the mezzanine by typical precast concrete structures that are used all over the entire project. The steel structures used to erect the typical bay of the mezzanine shown in Image 9.2.1 below will be summarized in Table 9.2.1 below.

Table 9.2.1: Current System	Name	Weight	Span
Columns	HSS 12" x 12" x 3/8"	78.52	17 feet
Girders	HSS 32" x 24" x 5/8"	225.8	32 feet
Beams	HSS 20" x 12" x 1/2'	103.3	32 feet

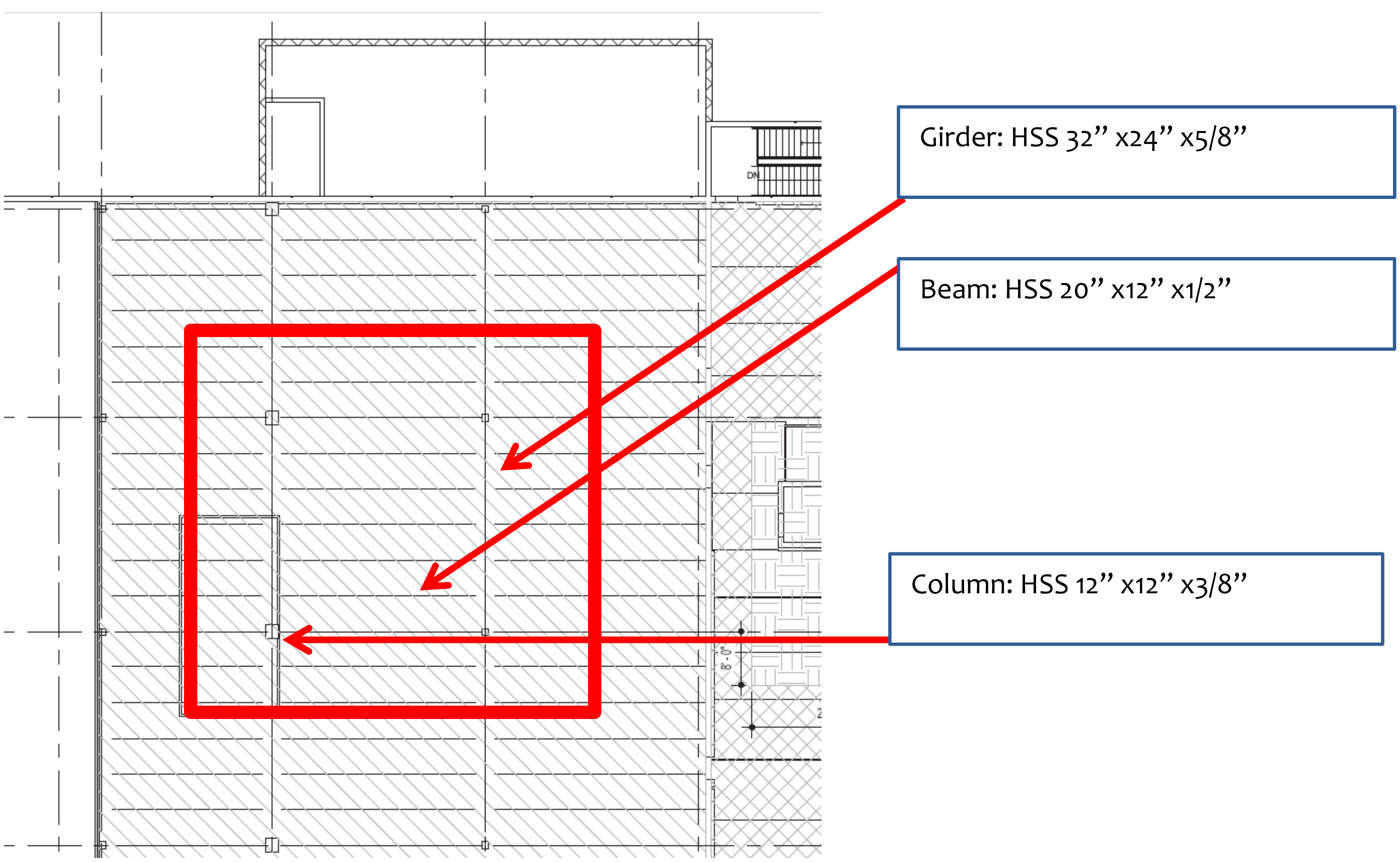


Image 9.2.1: Current Typical Bay

9.2.2 Loading of the current system:

This Mezzanine will carry the loads generated by the process equipment along with the 24 hours a day, 7 days a week labor operating the equipment. As per the calculations of the designers, the total cumulative load of unfactored Dead Load, Live Load & Collateral Load turns out to be 360 PSF spread over the span of the mezzanine minus the weight of the beams and girders. Using the equation (1.2D + 1.6L) the factored load turns out to be:

$$\boldsymbol{Factored\ Load}: \ 1.2\ (Dead\ Load) + 1.6\ (Live\ load) + Other$$
$$= 1.2\ (100\ psf) + 1.6\ (250psf) + 10psf\ = \mathbf{530}\ \boldsymbol{psf}$$

As it can be seen from the information above, the typical bay of the mezzanine is a 32' by 32' with a square tributary area of 1024 sq.-ft. So the factored load calculated above will be used to calculate the point load on exerted by the weight above directly onto the column in Lbs. Since the typical bay is a square 32' by 32', then calculating the tributary area will be an easy task since half distance to any of the columns' sides will turn out to be 32'/2 which means that the width and length of the load would be a 32' by 32' as it can be seen from the information on the pervious page. **Multiplying 32' x32' = 1024 Sq.-Ft**.

$$\boldsymbol{Point\ load\ on\ Column\ from\ Loads}:$$

$$530\ psf x\ 1024\ sq.ft =\ 542720\ lbs = \mathbf{543}\ \boldsymbol{kips}$$

Since the column will also be carrying the weight of the beams and girders that are not included in the loads mentioned above, then those loads have to be calculated and added to the weight.

Table 9.2.2: Typical Bay Steel loads	Number Of members in Typical bay	Name	Weight	Span	Total Weight
Girders	2	HSS 32" x 24" x 5/8"	225.8 plf	32 feet	14451.2 lbs. = 14.4kips
Beams	7	HSS 20" x 12" x 1/2'	103.3 plf	32 feet	23139.2 lbs. = 23.1kips
6" composite deck	1	Cast in Place concrete	75 psf	-	*modified weight by factoring = 90 psf

<u>So the total loads falling upon the columns will be = 543 kips + 41.4 kips + 23.1 kips =</u> **<u>607kips</u>**

The same method that was used to calculate the point on the column through the tributary area will be used to find the force per linear feet on each of the girders and beams.

$$\boldsymbol{For\ the\ Beams}:\ \boldsymbol{Weight\ by\ loads}$$

$$\frac{32}{6}\ feet\ (beam\ tributary\ length) x\ 530\frac{lbs}{sq.ft} = 2826.67\ plf = \mathbf{2.8}\ \boldsymbol{klf}$$

$$\boldsymbol{For\ the\ Girders}:\ \boldsymbol{Weight\ by\ loads\ by} + \boldsymbol{self\ weight\ of\ beam}$$

$$Loads:\quad 32\ feet\ (girder\ tributary\ legth)\ x\ 530\frac{lbs}{sq.ft} = 16960\ plf = 16.9\ klf$$

$$Total\ load\ on\ Girder = 16.9\ klf + (7x103.3\ plf) = \mathbf{17.62}\ \boldsymbol{klf}$$

Summary of loads on Steel Structures of Mezzanine:

Table 9.2.3	Loads
Columns	607 kips
Girder	17.62 klf
Beams	2.8 klf
6" Deck	90 psf

9.3 Parameters and assumptions:

In order to be able to change the system without affecting any other system, it has to be a controlled analysis where only 1 thing changing which is the structural steel mezzanine. This analysis will propose a precast mezzanine that will replace the steel system without any other changes. The assumptions and parameters of the system that will have to be maintained to attain a successful alternative system are the following:

- The columns that hold the mezzanine are anchored at the basement the same way the Precast 24x24 columns are holding the entire envelope => the load of the mezzanine is entirely independence of the envelope since the columns that carry the load transfer the load directly onto the ground and does not pass by the structure as it can be seen in Image 9.3 Section (5/S301) to the right.

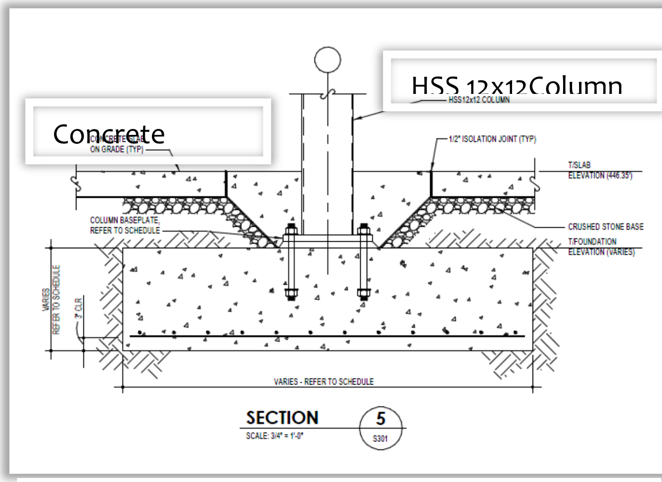


Image 9.3: Foundation Connection

- The current 12”x 12” HSS columns that hold the mezzanine are surrounded by process equipment. Since the details of the process equipment placement and operation cannot be known, it will assumed that there is enough area to expand the dimensions of the columns holding the mezzanine.
- For simplicity, the load calculations will be done for the center of the typical bay in which there is a higher load than there are on the side. So it is conservative to use the point load in a typical bay and apply it for the columns on the side which will normally take less force.
- Only very minor changes will be done to the overall design of the mezzanine to maintain the original design and maintain a controlled analysis.
- The weight of the 6” composite deck is included in the 100 psf dead load provided.
- There will be some changes in the foundation as a result of the change in the structural design of the mezzanine; however the cost, schedule and logistics changes would be a lot when compared to the effect on the foundation.

9.4 Loading of the Proposed System: (Breadth)

As mentioned earlier, the cumulative factored load upon the mezzanine is around 530 psf which will to be transferred to the ground through the following members respectively; Slab, Beams, Girders, Column. It will be similar to the loads carried by the current system since the dead and live loads did not change; however, there will be some differences as a result of the difference in self weight between the steel and the proposed precast concrete members.

The first change will be using a precast concrete solid flat slab to replace the 6" cast in place concrete used over the steel beams. The loads will have to be recalculated per the new structures and specifically the new self-weights.

Description	Span	Dimensions
Solid Flat Slab to be Used	32 feet	4'-0" wide x 22" deep

$$Weight\ of\ slab\ in\ psf:\ 150\frac{lbs}{ft3}\ x\ 22in\ x\frac{1ft}{12inches} = 275\ psf$$

$$Accumilated\ weight\ thus\ far: 530\ psf\ (original\ load) - 90\ psf\ (6"\ composite\ deck\ factored\ selfweight) + 275\ psf\ (proposed\ solid\ concrete\ slab) = \mathbf{715\ psf}$$

Description	Span	Dimensions
Beam to be used	32 feet	1'-0" wide x 2'-0" deep

Next step would be calculating the force on the beams:

$$Weight\ of\ beam\ in\ psf: 150\frac{lbs}{ft^3}\ x\ 2\ feet = 300\ psf$$

$$Accumilated\ weight\ thus\ far: 715\ psf + 300 = \mathbf{1015\ psf}$$

Description	Span	Dimensions
Girder to be used	32 feet	2'-0" wide x 3'-6" deep

Force on Girder:

$$Weigh\ of\ Girder\ in\ psf: 150\,\frac{lbs}{ft^3}\,x\ 3.5\ ft = 525\ psf$$

$$Accumilated\ weight\ thus\ far: 1015\ psf + 525 = \mathbf{1540\ psf}$$

Finally, the load will have to transfer onto the column.

$$Point\ load\ on\ Column: 1540\ psf\ x\ 32'x\ 32' = 1{,}576{,}960\ lbs = 1577\ kips$$

9.5 Designing the Concrete Column: (Breadth)

In order to be able to carry this extensive amount of self-weight, the dimension of the column will have to be stretched up to around 20" x 20".

The Column will have to have the following properties:

- *f'c (ksi)= 4*
- *Fy (ksi) = 60*
- *Tie = Rectangular Tie*
- *8 No. 18 (US)*
- *3 Bars in 20 in line*
- *AS = 32 sq.in*
- *Steel ratio = 0.08*

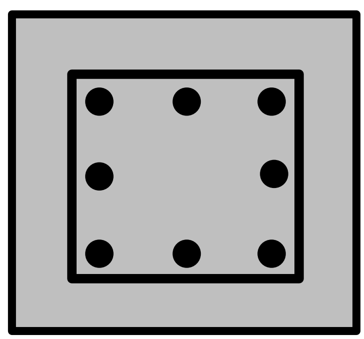


Image 9.5: Precast Concrete Column Design

With this concrete column design, the column can hold a load of 1649 Kips. This is satisfactory since the required load to be held by this column, Maximum Allowable Design (factored) load or capacity is Pu = 1577 kips.

A similar concrete column from suggested from industry professionals as provided by Nitterhouse cost $200/ft. as it can be seen in the financial analysis next section.

9.6 Financial Analysis:

In order to see if this analysis is worth the investment, the costs of each member should be compared to the alternative proposed option. The costs of the precast members were taken from Nitterhouse concrete while the costs of the current structural steel was taken from the RS means Building Construction Cost Data 2008; the costs include Manufacture, delivery and erection of the precast components. The RS means values will have to be modified for location and time as such:

$$Value\ x\ Time\ Multiplier\ (1.09 - For\ 3\ years\ at\ an\ inflation\ rate\ of\ 3\%)\ x$$

$$Location\ Multiplier\ (0.956 - Harrisburg)\ => Value\ x\ 1.042$$

Table 9.6.1: Members in a Typical Bay	**Description**	**Cost ($)**	**Number of units**	**Total Cost ($)**
Girders	HSS 32” x 24” x 5/8”	310 /ft.	2	$19,840
	2’-0” wide x 3’-6” deep	185 /ft.		$11,840
Beams	HSS 20” x 12” x 1/2’	201 /ft.	7	$45,024
	1’-0” wide x 2’-0” deep	160 /ft.		$35,840
Slabs	Cast in Place concrete	25 /sqft	1	$25,600
	Precast Concrete slab	20 /sqft		$20,480
Columns	HSS 12” x12” x 3/8”	259 /ft.	1	$9,522
	Precast Concrete 20” x 20”	200 /ft.		$3,600

From Table 9.6.1 above, we can calculate the cost of erecting the typical bay for each system which will provide a good basis for comparison. Since the costs are given per linear foot, they will have to be converted to cost per typical bay by multiplying it to the span. This will provide the total cost of erecting the typical bay for each system. The cost can then be modified and calculated to find the total cost of the entire mezzanine per construction type which can be seen in Table 9.6.2 below.

Table 9.6.2: System	Cost of erecting a typical bay	Cost per sqft	Cost of Entire Mezzanine (32,251 SF)
Precast Concrete	$71,760	$70.10	$ 2,260,795.10
Steel	$99,986	$97.64	$ 3,148,987.64

Table 9.6.3: Total Savings	Percent Savings
$ 888,192.54	28.21%

Through the calculations done in Table 9.6.3 above, the dollar amount saved by switching from a steel structure mezzanine to a precast concrete mezzanine is approximated to be $888,192.54 which is around 28% of the original's system cost. This financial analysis proves that it is a good financial investment in which money is saved by simply switching from a steel mezzanine to a precast concrete erected system.

In addition, after contacting the project manager, as a result of the mass fabrication, delivery, transportation et cetera, there will be cost reduction since everything will be ordered from one precast company instead of two trade companies; moreover, as a result of made-to-order orders and the mass purchasing of precast members for the entire building, the cost would be reduced even more. As for MEP coordination, the cost of the many trades that will work onsite to do their tasks on the steel mezzanine before pouring concrete will be reduced if it were prefabricated offsite along with the rest of the precast members used to construct the building. That would be the case since work could be performed off site in a closed controlled environment at floor level rather than in open environment at 30+ feet. In addition, it does require close coordination between all trades and preplanning to assure fabricated components can be transported and installed in a safe manner.

9.7 Schedule Analysis:

In only to have a comprehensive analysis which studies the proposal of designing and constructing a precast concrete mezzanine, studying the schedule and how that change would affect the project is very important. This schedule analysis will compare the schedules of the current system and the proposed.

Installation of the steel mezzanine was done in two parts. The mezzanine at Areas H and F was constructed from 18th May until 9th of June. Areas B and D mezzanine was erected from the 22nd of April until 1st of June. Total time it took to erect the mezzanine was 10 days for areas F & H, and total of 25 days for areas B & D. In addition, "*Form, Rebar & Pour Concrete on Mezz. Deck*" task takes 3 days. The next step would be waiting for the concrete to harden before taking any more steps.

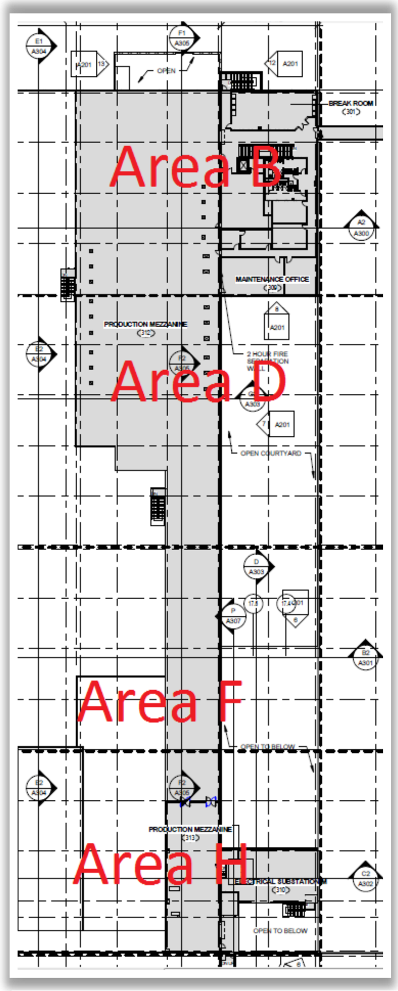


Image 9.7.1: Mezzanine Areas

Two cranes were utilized due to schedule requirements to construct the precast envelope. According to the Project manager at the project, either crane could have been used to set the mezzanine, and also said that if the schedule wasn't as tight, the mezzanine could have easily been set with either crane. The mezzanine was actually set after the precast was erected due to schedule requirements. From that, we can deduce that there will be no special or different crane used to erect the mezzanine whether it be from steel, precast, mezzanine or building envelop.

The way the schedule is set, utilizing the cranes to construct the mezzanine from precast members instead of steel would not affect the schedule by default from the perspective of work coordination or mobilizing cranes and other machinery and equipment for the mezzanine system since all that is required to erect the mezzanine after the precast envelope is to operate the cranes that are already there to pick up what is already there. The early finish date of erecting the precast was on the 11th of April which gives a lot of float time to utilize the crane again.

As per the schedule of the project, on average it takes 2 days to erect all precast members of a specific area. The mezzanine covers less than 10% of areas F & H, while it takes around 50% of areas B & D. So logically, since the process of erecting steel is very similar to erecting precast, there shouldn't be much a difference in time. The only difference is the connections required.

And from the same reasoning, the time it takes to erect a precast member in any area should be very similar to the time it takes to erect a precast member for the mezzanine.

The two sources used to analyze the schedule would be through the RS mean Building construction cost 2008, as it will provide this analysis with neutral general information regarding the duration and time it takes to perform the tasks, and the actual schedule used for the project, as it will provide this analysis with precise information that is actually based on the project itself and its performance, so it will provide a good indication of the duration and date to erect the mezzanine.

9.7.1 RS means estimate

According to the RS means information, Table 9.7.1 shows the daily output and labor hours of erecting each member which will used to figure out the time required to construct a typical bay which will provide a good estimate of the approximate time it would take.

Not all members could be found directly from the RS mean book, in that case, the closest best choice was chosen while comparing it with the members' weight to be as accurate as possible with estimating the duration of the process through the RS means.

Table 9.7.1 RS Means

Member	Quantity in a typical bay	Total quantity for entire mezzanine (33 typical bays)	Daily Output	Number of days
Girders	2	66	16	4.125
Beams	7	231	24	9.625
Columns	1	33	144	1
Slab	3	99	18	5.5

So the total time it would take to erect the mezzanine according to table 9.7.1 above is around 21 days. Since 2 cranes can be utilized to construct the mezzanine, the construction duration time would be reduced in half. So around 11 days would be the total time required for both cranes.

9.7.2 Using Schedule durations to estimate

The other method would be by using the schedule. It can be seen that erecting the precast walls for an entire area takes 2 days , erecting the precast concrete columns takes 2 days, erecting the precast roof members takes 3 days, the precast elevated slab takes a total of 5 days for 2 areas. Keeping in mind that the mezzanine covers less than 50% of the entire areas it is in. It approximately covers 2 and half entire areas. The duration will be adjusted accordingly to attain a more accurate duration.

The actual duration are summarized in table 9.7.2 below.

Table 9.7.2	Duration for an area	Adjustment for Mezz size	Duration for 2.5 areas
Girder	3 days	1.5	3.75
Beam	3 days	1.5	3.75
Column	2 days	1	2.5
Slab	5 days	2.5	6.25

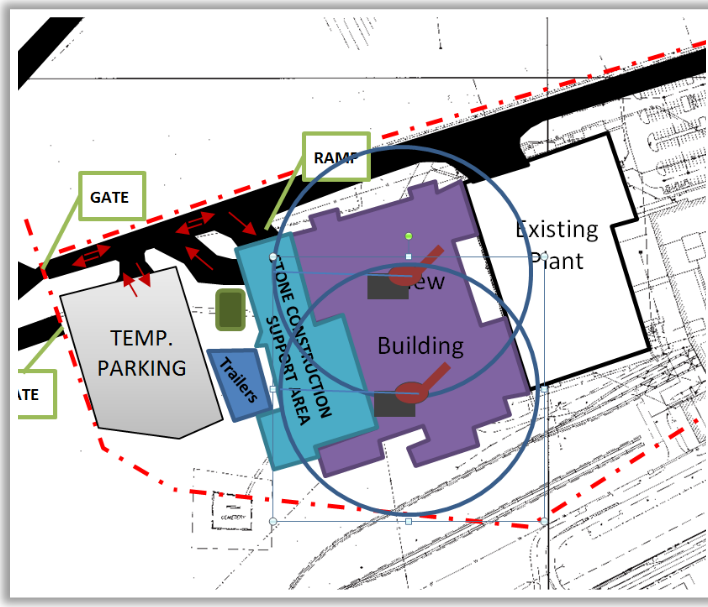
Total duration according this method comes to a total of **16.25 days** which is still less than the duration of erecting steel.

MEP prefabrication for the precast panels was used on the project as well. In this case, it will provide a reduction in duration when compared to the current schedule which requires MEP work for the mezzanine were afterwards concrete would be poured on the composite deck to cure. According to the schedule, MEP work for the mezzanine takes around a total of 20 days. Utilizing MEP prefabrication saves an extra 20 days when compared to the current method and system.

Compared with the time it took for the steel to be erected, erecting precast would be a better choice since it requires less time. The fact that a 28 days wait can be avoided open up windows to accelerate the schedule and begin working on tasks that otherwise would have required waiting for the concrete to harden before they can proceed with the tasks. As it will be shown in the logistic plan in the section ahead, the cranes that are used are mobilized to the center of the building from which it is operated to erect and construct the plant. Closer to the end of the task, the cranes will back up and continue to erect the roof until it exits the building and places the last precast piece. Thus, finishing the mezzanine at a faster time affects the critical path slightly since it does allow the cranes to proceed and finish with the roof which cannot actually begin until the mezzanine has been constructed using the cranes since the mezzanine does the require the crane to be in the center of the plant during construction.

9.8 Trade Coordination and logistics:

According to the project manager, all the steel and precast was delivered just-in-time for erection. This was the case for two reasons, only 1 precast panel or double tee could be hauled per trailer, in addition, there was limited stones laydown area to place the members. The same method would be used to erect the precast mezzanine. So, the actual coordination of trades plan would not be changed except for the fact that there are less trades and different workers working on site. All workers and tasks related to steel would be eliminated and precast workers and equipment which is already there would be used to proceed with the task for precast erection alone and not steel and precast. This would increase efficiency, effectiveness, safety and quality for many obvious reasons.



As it can be seen in the Site layout plans shown to the right, the two cranes have been utilized as a requirement. They will start erecting the members with the goal of ending the process by exiting from the west side of the building while still erecting the roof piece by piece until it exits the building from the left side of the building towards the "Stone Construction Support Area" shown to the right. The final step would be to erect the wall which was not erected with the rest of the wall to keep an egress available for the cranes when they finish their task.

The Mezzanine's actual erection plan starts with the southernmost crane to erect the first two areas (F & H), after which the next two areas would be erected (B & D). According to the schedule of the project and the project manager, both cranes will be available for erection of the mezzanine since erecting the mezzanine comes after the precast members have been erected. Hence, both cranes can be utilized at the same time to perform the job swiftly. In addition, as result of the huge range of the cranes that will be used, the southern crane can help speed up the erection of areas B & D since it is around 3 times larger than areas F & H. For a complete plan of the site layout for the erection, see Appendix E for full detail.

9.9 Connections:

Changing the system from steel to precast concrete requires new connections to hold the entirely precast mezzanine. Connecting and locking precast members together is very similar overall but is very different from steel connections. Since the entire project is from precast, the best way to figure out how to connect the precast for the mezzanine is to look at existing connections that exist in the building.

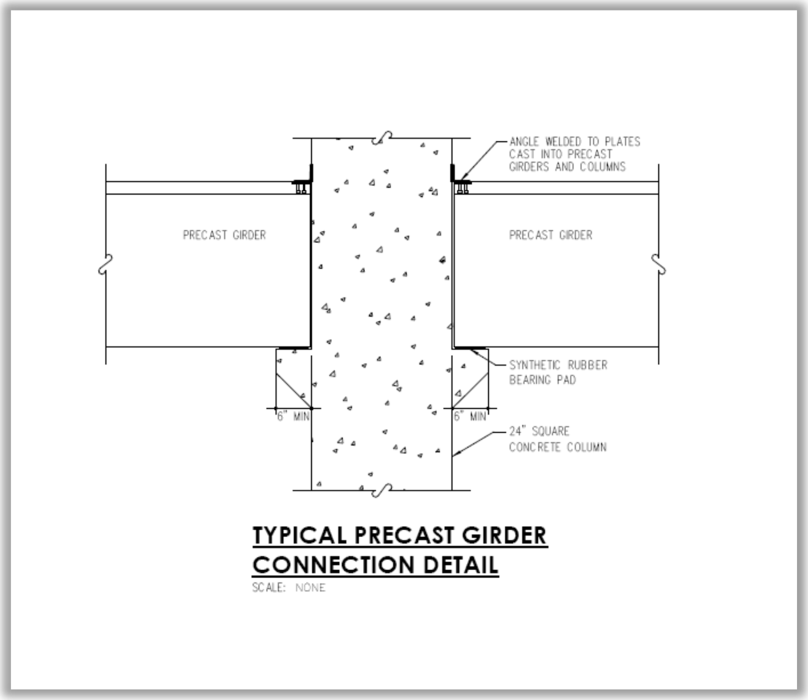


Image 9.9: Precast to precast Connection

Image 9.9 to the right shows how a precast girder is connected to a 24" concrete column. It is set from the bottom on a 6" min protruding block from the column in which the girder rests upon. Synthetic rubber bearing pad is used between the two members. From the top, the precast girders are locked by an angle welded to plates cast into precast girders and column. This method can be used for all precast to precast connections which will occur on the proposed precast concrete mezzanine.

9.10 Recommendation and Conclusion:

As it can be seen from the figures and calculations above, the weight of the proposed system is much heavier than the current steel mezzanine. This is as a result of the main property of precast compared to steel which is high relative weight to capacity when compared to steel's low weight to its high capacity. So the implication of using concrete over steel would be the high self-weight that has to be accounted for.

However, the proposed precast concrete system would generate $888,000 of savings when compared to the steel mezzanine. This is mainly because the low-weight to high strength capacity does not come for a low price.

There are many factors to choose between a steel structure and a precast structure. The main two factors that greatly affect the decision making is Cost and schedule; and from this analysis it can be seen that precast concrete structured mezzanine has advantages in both fields. If design space of members or height was a factor or even transportation, then steel may have been a better option. However, that is not the case at all, on the contrary, since the entire building structure is from precast concrete units, then it would be a better option to eliminate all the rest of the other trades on site for a unified “precast concrete” structure. This would provide many benefits from the aspect of reduced trade coordination, less congestion, less specialized equipment and machinery for each trade, and so on.

From another perspective, the main reason why the entire factory was from precast concrete is because a concrete envelope is a better option for food processing plants from the perspective of cleanliness and hygiene, and FDS regulations. And since the FDA can suddenly show for an inspection, that is a very important factor.

The reason why the mezzanine was from steel was as a result of miscommunication and delayed MEP coordination; hence, if the alternative option is actually a better options from many perspectives, then from a Value engineering perspective, the change from steel to mezzanine will yield benefits to the project process and in addition to its low cost.

Overall Systems Comparison Table 9.10:

Table 9.10: Summary of both systems

Typical Bay Steel loads	Number Of members in Typical bay	Span	Name	Weight (plf)	Total Weight (kip)	Cost ($/ft.)
Girders	2	32 feet	HSS 32” x 24” x 5/8”	225.8 plf	14.4kips	164
			2’-0” wide x 3’-6” deep	1050 plf	33.6 kips	185
Beams	7	32 feet	HSS 20” x 12” x 1/2’	103.3 plf	23.1kips	
			1’-0” wide x 2’-0” deep	300 plf	67.2 kips	160
6” composite deck	1	-	Cast in Place concrete	75 psf	*modified weight by factoring = 90 psf	
22” Solid Slab			Precast Concrete slab	275 psf		20

10.0 Analysis 4: Bathroom prefabrication

10.0 Problem Identification:

The main issue that this problem is intended to solve is that there will be many trades on site in the bathroom/locker area on the second floor in area O that will start simultaneously. For that reason, the use of prefabrication in the bathroom would be studied. The bathroom is designed to have CMU walls with embedded piping and electric rough-ins.

10.0.1 Goal:

The Main objective of this analysis is to be able to solve the issue stated above through the use of prefabrication of the bathroom walls which will have the piping and electricity embedded with a precast concrete wall. This idea was brought up since the entire project is a precast concrete erected project with many of the precast concrete members prefabricated with MEP penetrations and embedded piping and wiring.

10.0.2 Procedure:

Develop an analysis that studies all the aspects that will decide on the feasibility and applicability of this analysis.

- Study what parts can be prefabricated from the bathroom/locker area
- Site Logistics and Hoisting of the prefabricated walls
- Connections of the precast system to the structure
- Tasks after locating and installing walls
- Benefits to prefabrication
    - Quality, environment, less waste
    - Schedule
    - Cost / General Conditions
- Applicability with BIM

10.0.3 Possible Resources:

- Previous projects with similar intentions
- Educational Background from previous AE courses
- PSU AE faculty
- Engineering Library
- Online resources

10.0.4 Projected outcome:

The project projected outcome is that this analysis will prove to prevent congestion, which is the main issue to solve from this analysis, and save time majorly in addition to many advantages that will be gained. Cost could also be reduced if this research was implemented correctly at an earlier time.

10.1 Background information:

The West Fuala Expansion project is a project in which extensive amounts of prefabrication has been utilized to reduce costs and schedule time as much as possible; however, in some areas, such as the bathroom locker area, extensive toilet piping is required for a small space. Moreover, the type of wall structure that will be used in that area is CMU which is not a simple process.

The request of prefabricating the piping system in the bathroom/locker area room was from the superintendent, BIM engineer and the project manager after asking them about potential areas of work or tasks that could be improved. As a result of the extensive work and the issue that arises from major congestions within the fit-out areas and tasks, prefabricating the piping system would result in major advantages from the aspect of schedule majorly in addition to many intangible benefits that would be of great benefit and importance to the project.

This Analysis will study the application of schedule acceleration through prefabrication of the bathroom / locker space in area O, the office on the second floor. The goal is to be able to devise a method of prefabricating the piping system and be able to deliver and install the system in a better sequence and logistic plan that the current.

The overall plan would be to prefabricate the precast bathroom walls with the piping and electric rough-ins off site and then deliver it to the site after which the walls will then be hoisted and connected into place.

The bathroom would be prefabricated as precast concrete walls with the piping system already embedded in. The next step would be hoisting and connecting the walls using the crane already used in site in the same way precast members were hoisted, connected and placed in their specific location. The final step would be to install various bathroom pieces, from toilet seats, sinks, bars and so on, the same way it would have been installed if the current method was followed.

10.2 Studying the area to decide on the prefabrication process:

The first step in studying this analysis is to breakdown and study the various components that make up that area of bathrooms and lockers, keeping in mind that the main goal of this analysis as requested by the project team is prefabricating the piping system. This method will is expected to achieve the main goal of prefabricating the piping system and beyond through the various benefits that will be attained through early prefabrication of the system.

As it can be seen from Image 10.2.1 which shows a plan view of the area, the main units to be prefabricated are the piping system which are currently planned to be encased in the CMUs.

The layout of the piping system for that area can be seen in image 10.2.2 below. This isometric view clearly shows all components of the piping system that would otherwise be invisible within the concrete masonry units.

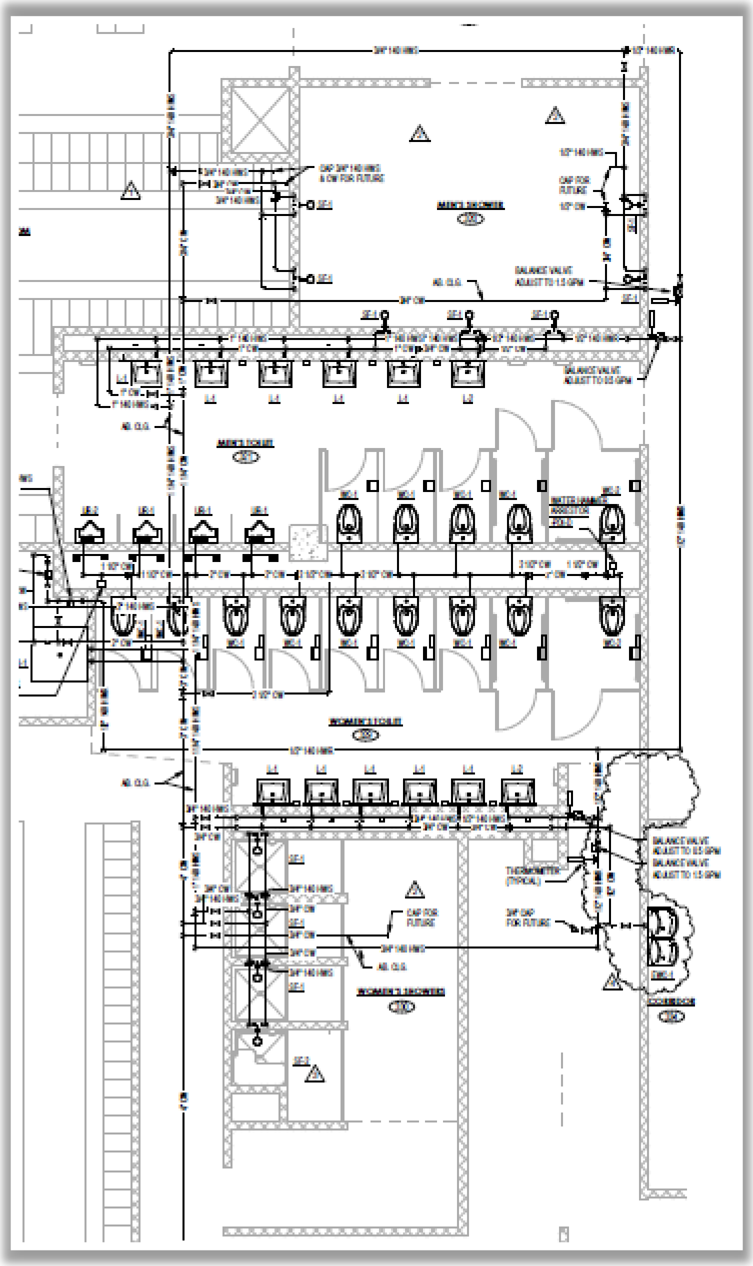


Image 10.2.1: Plan View of Area O

Building information modeling will have an important role in the success of this plan. The initial use would be to produce and submit the plans of the bathrooms and piping system to the prefabricating company. In this project, BIM has been used for clash detection and 3D coordination uses. Since it has been extracted from the BIM model, then it can be safe to say that all clashed have been detected. Hence, all that is left in this step is for the manufacturer, who took the task of manufacturing all the precast walls and floors and so on along with the piping and electric rough-in embedded inside the structure, is to build these walls as per the specs and drawings provided. This step would be done earlier in the schedule in order to have the pieces prefabricated, produced and delivered at the right time as the rest of the precast concrete members have been for this project.

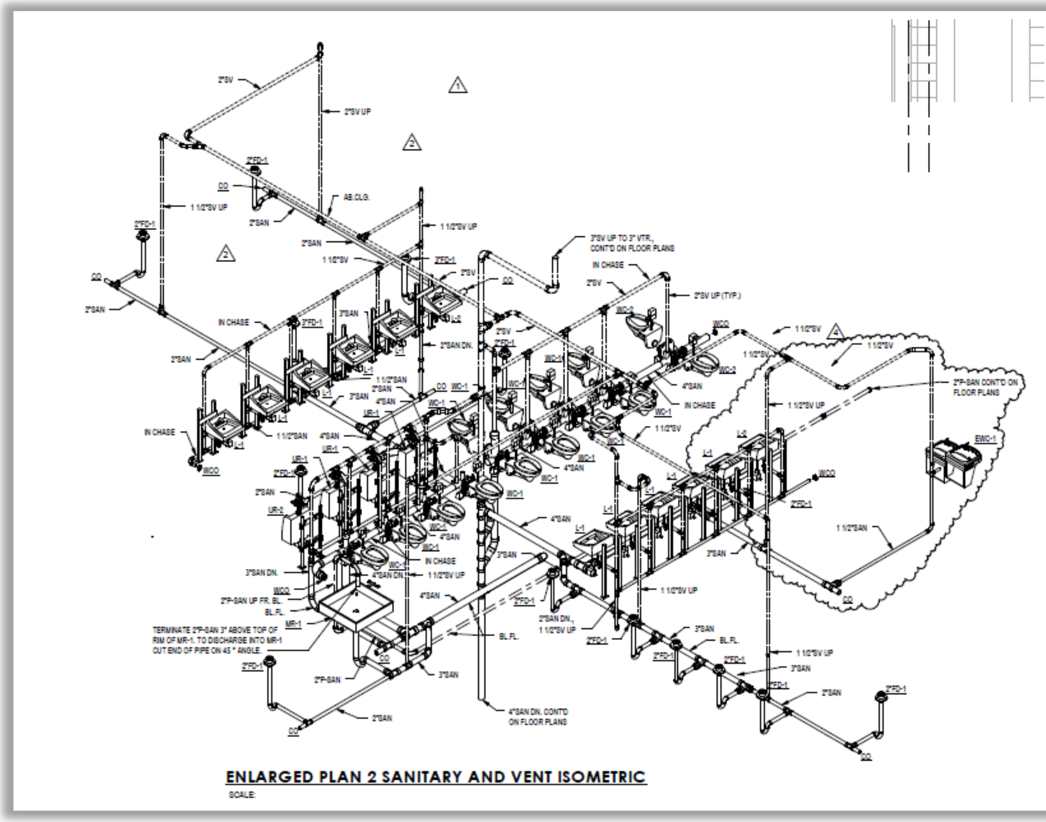


Image 10.2.2: Isometric View of Area O

10.3 Precast Concrete Bathroom walls:

In order to perform a good analysis, all methods and systems have to be considered and analyzed to decide on the best method specifically for the West Fuala Expansion. There are three main typical methods/systems of prefabricated precast bathroom units which will be considered and assessed according to the current project:

System 1: Precast concrete cell completed and finished wall and floor prior to delivery to site.

This system, the bathroom would have to be cast as volumetric concrete cells or walls pre-finished with floor and wall finishes before delivery to site. The following step would be hoisting to location where the mechanical and electrical services will be connected to the mains of the building. Finally, the bathroom components and sanitary fittings will be installed inside the building.

Image 10.3.1: System 1

System 2: Wall panels and floor tray separately lifted and assembled at site.

The second system is different in that the floor tray will be lifted to position and set up accordingly. Then, the wall panels will be lifted and assembled at site with the ceiling and sanitary fittings at the end accordingly.

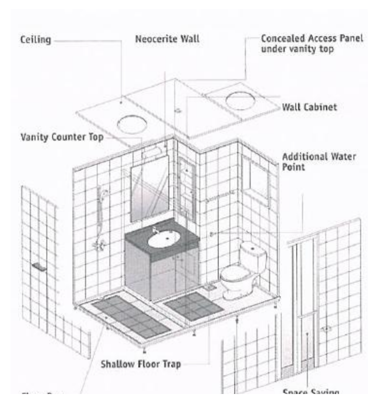


Image 10.3.2: System 2

System 3: Wall panels and floor trays pre-assembled in factory prior to delivery to site.

In this case, the wall panels and floor tray will be pre-assembled in factory prior to delivery to site. The only step is hoisting the prefabricated precast bathroom to location and connecting the mechanical and Electrical System to the mains of the building.

Image 10.3.3: System 3

10.4 Assessment according to current conditions, location and project:

All precast bathroom systems mentioned earlier share the common advantages and disadvantages of prefabrication; however, there are some restrictions and issues with each.

System 1 seems to be perfect for the job since it has the entire bathroom cell/walls connected and hoisted into place. The finishing of the bathroom will be done using the same original methods except that there will be less site congestion with less trades and tasks to perform. The problem here is that the entire bathroom cannot be prefabricated into precast as a result of the sheer size, and neither can it be transported. In addition, there are no regional manufacturers that can do the task of precast prefabrication of bathroom areas; all the manufacturers were international companies from Europe and Eastern Asia.

The difference between system 1 and 3 is where the bathroom components and finished will be installed with 1 being on site and 3 being in the factory. Once again, there are no manufacturers that can build the precast concrete bathroom in the region and neither is there a manufacturer that can take care of installing the bathroom components within the factory. So both systems cannot be used.

System 2 provides a much more doable method. There is no manufacturer that can deliver these types of systems in this region although they are widely used in other areas in the world; so the other option to implement System 2 would be ordering the precast walls separately from the current precast manufacturer and then use the same team and tasks as the current schedule to prefabricate the bathroom on site

First off, the bathroom will not be prefabricated as one unit but as precast walls that will be hoisted and then connected as any precast wall. With this method, hoisting the walls with the current crane would not be an issue since it erected massive precast walls with larger size and weight. Moreover, structurally connecting the precast walls to the structure would be using typical precast-to-precast connections.

10.5 What to prefabricate:

The piping system runs all over the place, from that sense, not all piping can be prefabricated within the walls and not all walls can be prefabricated. A more realistic and simpler approach would be prefabricating the piping and walls in the same plane, which can be seen in Orange in Image 10.5. This method has been chosen for easier prefabrication of the walls by the manufacturer, for simpler conection methods from a structural and piping connects perspective and to have a simpler system (when compared to the complexity of the alternative of prefabricating the entire area).

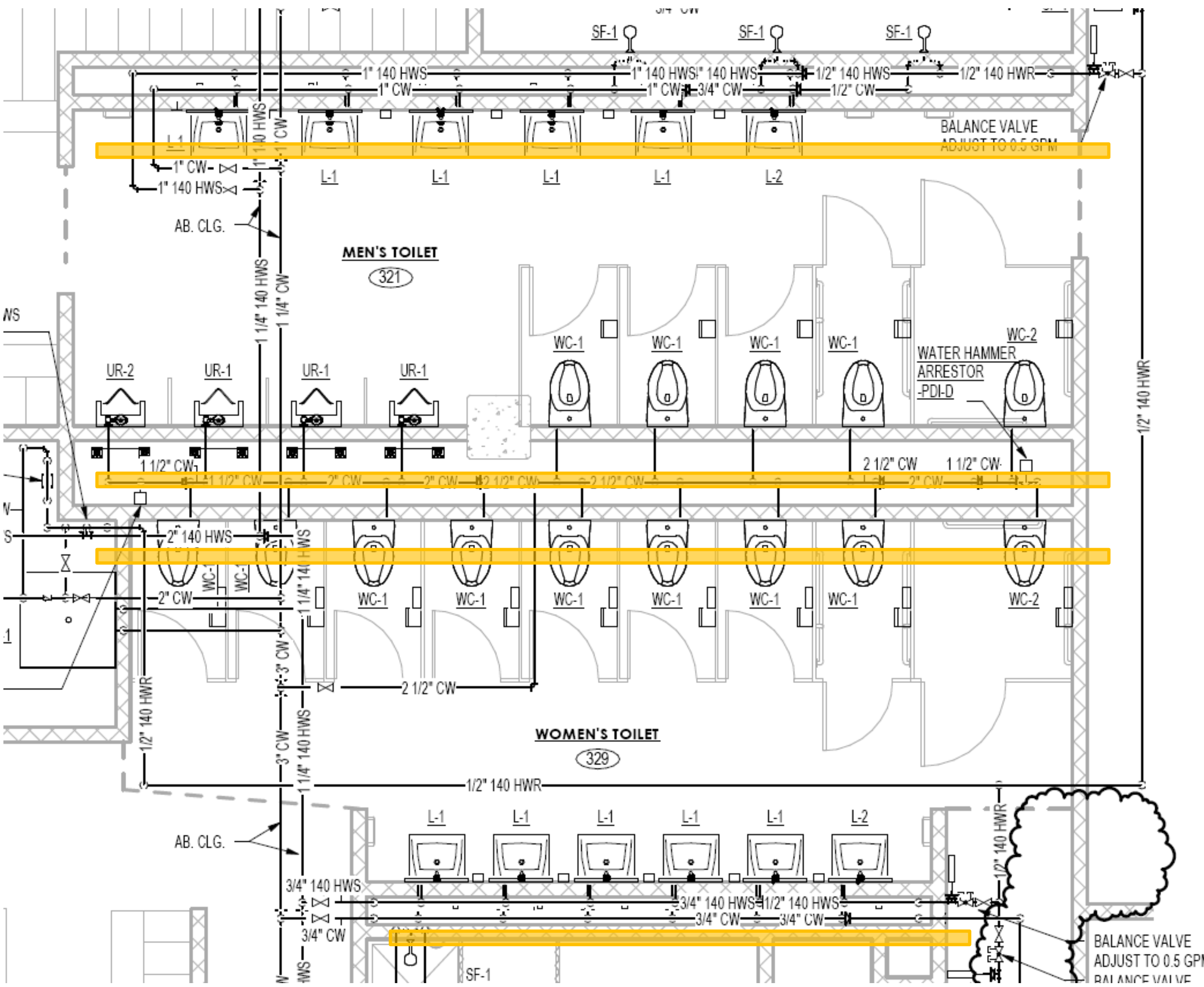


Image 10.5: Walls to be prefabricated in Orange

10.6 Connecting the Embedded piping to the main system:

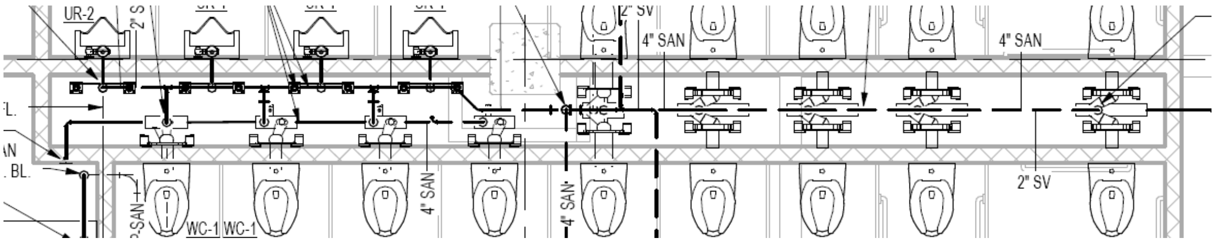


Image 10.6.1: Close-up view of the area

Since the wall will contain the prefabricated piping and electric rough-ins, one of the major concerns is how these precast prefabricated walls will connect to the main electric and plumbing system.

The current piping system as can be seen in Image 10.6.1 above, runs vertically along the bathroom walls and ends up at the bottom as an Inverted T that connects the bathroom fixture from one side (sink or toilet) to the other side to connect to the pipe running horizontally and connecting all bathroom piping before connecting to the main pipe. The same method will be used while the piping is embedded in the precast bathroom walls. The piping that will connect to the main piping system will be protruding out from the wall from the non-visible side of the precast wall. It can then be easily connected to the rest of the piping system in the bathroom. In this scenario, the piping connecting the wall to the main piping system will be exposed since it is not embedded in any wall or structural system but will not be visible to the public since it is from the other side of the wall and encased between two walls. With this method, the walls that will stand next to each other will only have a structural connection since the piping system will connect from the outside as it can be seen in Image 10.6.2 above.

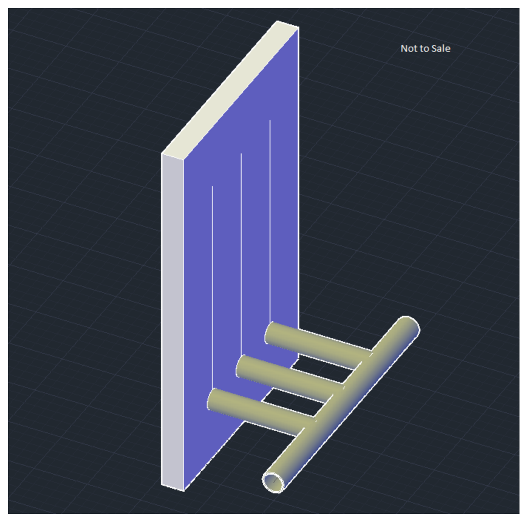


Image 10.6.2: AutoCAD drawing of the precast wall with piping system connection

As mentioned earlier, the restrictions here is that not all piping can be embedded inside the bathroom walls since some will have to be exposed to connect the piping together in addition to the fact that the piping system, as designed from the beginning, will be exposed. Moreover, not all walls can be prefabricated with the piping since there are some complex connections that cannot be prefabricated and require connecting in the site after the walls have been placed.

10.7 Current bathroom walls:

As mentioned previously, the current interior walls to be replaced in Area O are concrete masonry units while the exterior walls are precast concrete walls. They are 12" CMU walls with strength of 2000 psi in addition to the 2000 psi of the grout as per the construction drawing. The height of the walls is 17 feet with a total length of 114 feet which is the cumulative length for the CMU walls that will be prefabricated. A total of around 2180 CMU's each with the following dimension: 12" x16" x 8". Image 10.7.1 below is a section of the CMU in Area O.

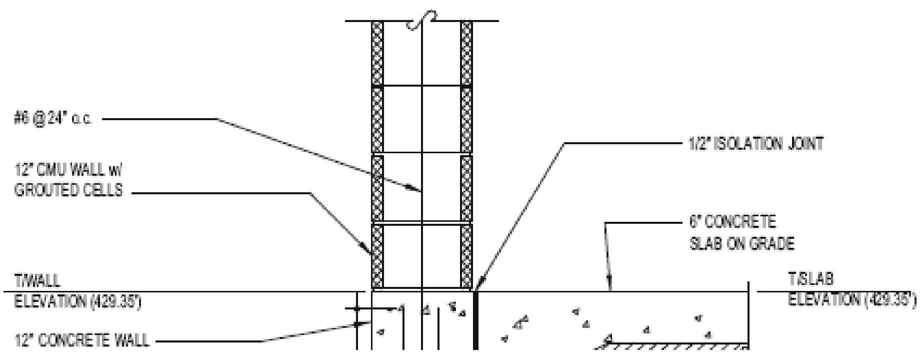


Image 10.7.1: CMU cross section

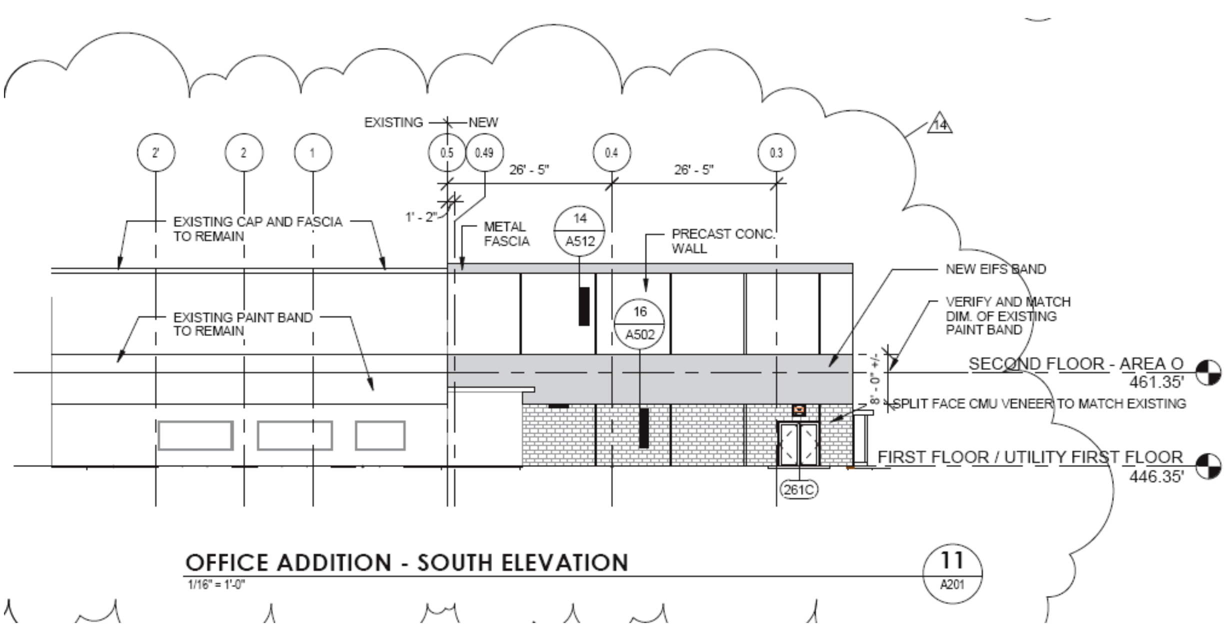


Image 10.7.2: Area O elevation

10.8 Proposed precast concrete Walls:

This proposed system that will replace the CMU walls in Area O with the intent of reducing congestion would be precast concrete walls. They will be dimensioned exactly as the current CMU units: 17" height, with a thickness of 12". The load bearing capacity will be 4000 psi to match the current bearing capacity of the CMUs and the grouting in addition to the thickness. There will be a total of 4 walls to be prefabricated. The three walls that can be seen in image 10.8 below that have a length of 32 feet will be erected as three separate walls; the precast panels would have the following dimensions: height 10.6 ft x12in thickness x 17 ft. The 18 feet wall would be erected as two walls with the following dimensions: 9 ft x 17 ft x 12 in. The cumulative length of the walls to be prefabricated is 114 feet and the overall square footage would be 1938 Square feet of exposed wall. Since the bearing capacity of both systems per square inch is the same, a structural analysis won't be necessary since both systems are built to sustain the same loads.

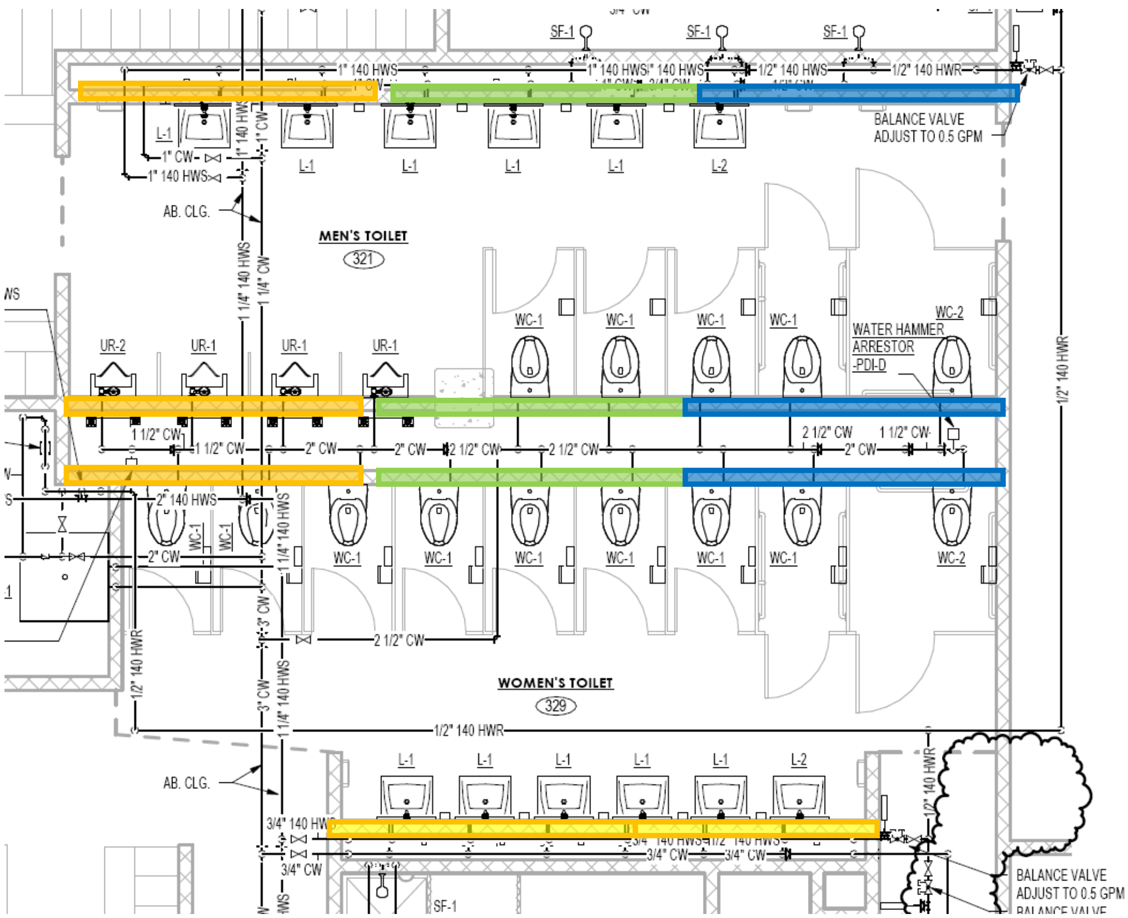


Image 10.8: Different walls to be connected

10.9 Schedule Analysis:

The method of calculating the duration of both systems would be using the RS mean Costworks. Once again, the RS means does not produce exact duration of the system since there are many factors that affect the duration but are not accounted for in the RS means; on the other hand, it provides a good estimate and a good sense of direction on how the duration of both systems relate.

According to RS mean information, Table 10.9 shows the daily output and labor hours of erecting a unit which would be used to find the duration of both for all walls.

Table 10.9: Systems	Quantity	Daily Output per SQFT	Number of days
Precast Concrete	11	1400	1.38 days
CMU	2415 units	300	6.46 days

So the total time to erect the precast walls according to Table 10.9 above is around 2 days when compared to the 7 days of CMU units in that area excluding the system embedded inside.. So a minimum of 5 days will be removed from schedule.

10.9.1 Comparison to current schedule:

As per the schedules provided by the contractor, the default method of constructing the bathroom/locker areas piping system and walls starts from June 22nd until September 7th, approximately around 45 days of construction. In addition, the schedule mentions around 13 tasks that will take place in that time frame. Even though not all are necessarily involved in the piping system and the walls, they are all located in the same confined area which is the main reason for the project team to request a prefabrication plan for the piping system in that area which would achieve a major difference by itself from the perspective of reducing congestion.

The main tasks that will be performed and are planned to be prefabricated are: the installation of the masonry walls in that area, with a duration mentioned in the previous paragraph; In-wall plumbing, which takes place from the 24th of June until the 19th of July, which is a 25 day task; in wall electric rough in, which takes place from the 27th of June until the 7th of September, a 40 day duration task. It can be seen that plumbing and electric rough in is a tasks closely dependent on the task of installing he concrete masonry unit walls.

It can be clearly seen from the figure above in addition to general knowledge of the process of prefabrication and its benefits that this method would shave off 5 days of the schedule. In addition, since a lot of work depends on the completion of the area's walls, i.e. it is clearly a critical task that affects the critical path of the schedule in this area, completing this task would cause schedule accelerate and reduction at the same time since finishing this task would allow the progress of other tasks that were dependent on it.

10.10 Cost Analysis:

The next step in this analysis would be comparing the cost of the original system to the proposed which is big factor in deciding on whether to consider this change. The cost of the precast concrete bathroom walls and the CMU units will be taken from the online Costworks software from the RS means website. The location adjustment factor was specified for Harrisburg, PA using values as of 1st quarter of 2012. The exact units could not be found for all units so the values were taken for the closest units considering volume, dimension and loading capacity Table 10.10 below shows a summer or both systems with the cost.

Table 10.10: Systems	Dimension	Cost per SQFT	Cost for entire square footage of walls
Precast Concrete	20’ x 10’ x 12”	55.76	$ 108, 063
CMU w/ grout including labor	12” x 16” x 8”	27.40	53,101.2

The precast system found in the RS means Costworks has the same thickness and bearing capacity as the proposed precast system, 12” thickness and 4000 psi, since this was the deciding factor differentiating the costs of the precast systems. The precast concrete cost per square feet includes the cost of the material and labor. The CMU cost includes grouting, material and all necessary work, all accumulated. The area of the entire system is 17 feet by 114 feet which is 1938 square feet.

We can see that the cost of the precast system is around double the cost of the CMU current system. Even though the RS means Costworks values are not for the exact units proposed to be installed and were actually for the closes units with the same spec; it nevertheless, provides a good indication on the difference in cost and the change will affect the price of both systems. The material and labor cost of switching from CMU to precast would be $54,961.80.

The cost of placing the mechanical and electrical rough in would not be affected since the same crew that would have installed them would be used to prefabricate and install them in the same way in the precast concrete factory.

10.10.1 Prefabrication logistics and Transportation:

Prefabrication of the systems that will be placed inside the precast panel has to be prefabricated in an area nearby the Concrete factory after which it will be transported to the factory to be placed after which the precast walls would be made and cured as per the specifications which would then be delivered to the site for erection.

The Warehouse that be used:

- Lancaster County, Denver, PA
- Industrial Use
- 117,000 SF
- $4.35 per SF
    - Area Used = 3000 SF
    - Total rental price = 1500 SF x $ 4.35/ SF = $6,525

10.10.2 Transportation Details:

The flatbed trucking trailer size would be the following: Width, 8.33 feet, Height under 8.5 feet, length 53 feet, handle approximately up to 48,000 lbs. of freight weight. The proposed precast panels that will be used cannot be transported through regular means since the units to be transported are of huge sizes. Permits would be needed for oversized loads since the height will exceed the 8 feet max height which is regulated by the traffic authorities. This is not considered a downfall since it is an industrial plant which was erected using massive precast panels which have been transported with the required permits.

Transportation cost from warehouse to Concrete factory:

- $2.68 per mile for a Flatbed truck
- 2.4 miles distance from warehouse to factory (8 min)
- 50 miles distance from factory to project site (56 min)
- Cost = $ 140.432

10.10.3 General conditions:

An indirect benefit of prefabricating the systems and walls in the bathroom/locker area in the second floor would be a reduction in the general conditions cost. The mentioned before, the general conditions overall cost for 22 months of construction was estimated to be $ 992,000; Hence, each day has an average cost $1,503. Since this task is actually on the critical path, then the reduction of 5 days from the schedule will actually directly reduce the overall time of the schedule and the general conditions cost in a relative manner. Assuming the previous discussion is true; the total general conditions saves would be around $7,515.15

Summing the costs, the net cost of switching from CMU to precast would be $54,112.08

10.11 Site Logistics and Hoisting of the prefabricated walls:

Figuring out a way to hoist the prefabricated pipe embedded walls into area O's bathroom/locker area is not an issue at all neither will it cause substantial costs or logistic issues since there will be precast concrete walls erected for area O. The crane that will hoist the precast walls into place will also be used to hoist the prefabricated bathroom walls into place. As it can be seen from Site Layout Plan in Appendix 10, the crane which will be utilized to erect the precast walls can also erect the prefabricated walls since it is within reach.

10.12 Constraints:

There are a lot of construction constrains that have to be considered when analyzing the precast wall construction process and design such as:

The prefabricated walls had to be designed with a length of less than 12 feet since that is the max size of precast panels used for the entire project as stated in the drawings and specification.

The erection sequence will have to be modified. The current sequence of erecting precast in area O would be erection the exterior walls in Area O followed by placing the CMU walls and the rest of the tasks. The slight change would be that the last (fourth) exterior wall would be erected last where the precast bathroom walls would be erected in that time. The final step would be installing the last side of precast concrete walls in Area O after which the tasks will be performed in the same manner as the original schedule except that he precast bathroom walls will have been already installed. This method avoids hoisting from above the exterior walls through switching the sequence of erection of precast concrete on Area O.

Connecting the CMU walls to the precast concrete system would be through the same method as the current method of connecting CMU to precast all over the project.

Coordination with other trades would be a major concern in this process. From the design stage, BIM coordination and 3d clash detection is very important for the success of the design of the precast bathroom walls. During the construction phase, the tasks that will occur between the warehouse prefabrication and factory production and delivering has to be closely related. Mainly because the fabrication of precast panels cannot begin until the MEP team prefabricated the piping and electric rough-in and deliver them to the factory and in order to maintain "delivery and direct erection without storage" method that this project is utilizing which was mentioned earlier.

Onsite coordination for when the MEP trades comes in after the precast bathroom walls have erected would be an easier task, this is mainly because the team itself has prefabricated the piping and electric rough in the ware house and placed them for prefabrication. So the tasks that they perform will be reduced which will reduce the congestion since there are less tasks and less trades on site.

10.13 Connection details:

The system would be connected the same way as the CMU walls would have been connected. The precast walls would be attached to a '26GA Galvanized steel trim with finish' to match wall panel along with 'precoated bellows with expanding foam backing' as it can be seen in Image 10.13.1 to the right. Since there has been no major changes to the system, there won't be much of a difference when it comes to completing and performing the steps following installing and placing the precast walls.

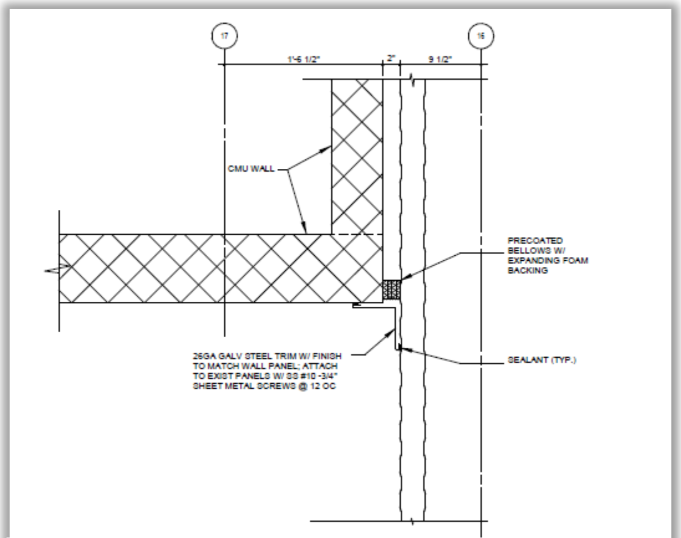


Image 10.13.1: bathroom Wall connection to Precast Wall

Image 10.13.2 shows a different method of connecting the CMU to precast.

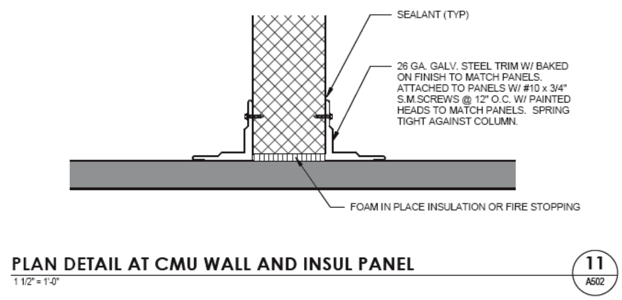


Image 10.13.2: CMU to Precast connection

10.14 Benefits to prefabricating the system:

The analysis of prefabricating the piping system in area O was requested by the project team at the west Fuala plant expansion project as a result of the major congestion that is planned to occur at this stage and area in the project. So the main goal to achieve in this analysis is to reduce the congestion in that area. If the piping system was prefabricated without any problem such as increased costs, then the goal of this analysis has been achieved.

10.14.1 Offsite prefabrication:

Performing construction work offsite especially through prefabrication produces many benefits to the project. First of which is reducing the risk of conducting work on the project site. The fact that the walls will be prefabricated in a controlled environment adds to the safety factor which is very important fact that affects the project progress itself in addition to the insurance cost and reputation of the contractors and the personal life and safety of the workers. This is mainly because the job would be done by assembling the components in a manufacturing factory off site.

Moreover, since the work will be performed in a controlled planned environment, self-supporting ready-made components are used, so the need for formwork, shuttering and scaffolding is greatly reduced. From another aspect, congestion will be reduced greatly which is the main goal since he job will be broken down into many tasks which would be done offsite, hence more space for other trades to do their work which further supports safety, but this it would be an increase in safety on site. Prefabrication increases safety of work and workers off site and on site, this by itself could be a reason for prefabrication.

Quality control would also be achieved in many aspects. Through factory prefabrication, quality can be even assured and worrying about faults and inspections is dramatically reduced. From another sense, reducing congestion on site will increase work quality of the other trades that will be working in the space. The same reasoning allows for more efficiency per workers on site and off site.

Environmentally, if work is performed off site in a factory controlled process, waste would be majorly reduced if not eliminated or recycled. This could be a priority if achieving a certification is a goal or simply trying to reduce waste for environmental reasons. Another reason to prefabricate is to avoid or reduce performing work in a bad weather or hazardous environment.

10.15 Option of Prefabrication of bathroom component before erection:

As stated earlier, the main tasks to be performed for this analysis would be: Design development, Prefabrication of piping and electric rough-in in ware house, deliver to factory, manufacture the precast concrete walls, deliver them to site, hoist, connect and then continue on with the schedule normally. With this specific sequence, more can be achieved through prefabrication of the bathroom finishes before erection.

The sequence will change to: Deliver precast concrete walls with the MEP system embedded, Settle the units in an open area on site, Coordinate the team to continue the 'prefabrication' process by prefabricating the bathroom components and finishes and connect them to the bathroom walls, The final step would be to place and connect the walls as mentioned earlier.

The effects of this option is that the congestion in that area will be further reduced since a lot of tasks will be performed ahead of time on site and for that reason, there will be less workers in area O. This can produce further schedule acceleration and possibility of critical path reduction.

10.16 Finishing the Bathrooms:

This process is regarding finishing the area by installing the various components that area part of the bathrooms system in that area. The main components of this area are shown on Table 10.5 to the right.

The same crew would perform the task along with the same process and steps. Having the same methods as mentioned earlier reduces the differences and maintains stability since it did not change from the initial main plan with the fact that there will time reduction. The exact time that these tasks will save could not be calculated in detail, but it surely has its benefits from schedule reduction, less trades and workers, better quality and so on.

Finishing's Material Description:

- Toilet Paper Dispenser
- Paper Towel Dispenser
- Sanitary Napkin Disposal
- 24"x26" mirror
- Soap dispenser
- 36" Long Grab Bar
- 42" Long Grab Bar
- Electric Hand dryer
- Extra Heavy Duty Shower Curtain Rod/ Stainless Steel Shower Curtain Hook / Vinyl Shower
- Horizontal Shower Grab bar
- Cloths Hook w/ Bumper
- Double Robe Hook
- ADA shower seat
- Soap Tray

10.17 BIM, Green & Prefabrication:

Prefabrication is an old, well established method of construction used for centuries. However, it only became slightly popular in the construction industry in Europe since the 20th century. One of the major applications that utilize prefabrication was in the United Kingdom to replace houses bombed during World War 2. The sections were assembled in factories to save time off site and reduced the overall cost; and that in its essence is the purpose and main goal of prefabrication in the construction industry and in any other application.

However, only until recently that it became a pursued method. It was not so popular before since even after AutoCAD was establish, there were still major issues that rose suddenly during the construction phase and it is normal and expected for issues to happen during construction. For that reason, Cast-in-place concrete is still widely used in many areas around the world including the USA. The only other application which made use of prefabrication was the production of steel, but that was because it had the potential to be a consistent established unit of construction, and that is the case now.

The sudden major development that caused and called for the reemergence of prefabrication and modular as a new trend is directly connected to the rise of BIM and green building. The emergence of BIM has a direct effect on the design and construction process of projects and buildings in addition to the collaboration of the many different trades and professionals working on the project. According to "Business Value of BIM SmartMarket Report (2009)", the key benefit of BIM is enabling the increased use of prefabrication and modularization, which in turn improves worksite productivity and overall project return on investment. The use of BIM in the reemergence and the increase in popularity of prefabrication is unquestionable.

10.18 Recommendations and Conclusions:

According to this analysis, prefabrication of the piping system of the bathroom/locker area is very possible in a very modern manner which would yield many benefits. The many benefits that will be attained from safety, quality control, schedule time reduction and the main target of reducing congestion in that area would all lead to the fact that this method would prove to be very beneficial to the overall success of the project. However, there will be a large cost impact if the system was changed from CMU to prefabricated precast walls which will greatly affect the decision making.

Since the entire project is prefabricated precast facility, designing and prefabricating the bathrooms would be very beneficial for the project if it were planned and prefabricated from the beginning. Although the attempt to reduce congestion at this time of construction would be very challenging, it would be worthwhile to investigate and contact the manufacturer. And since connections are already established with the manufacturer, adding to the already made prefabricated orders and deliveries that are on-going should be a simpler task than otherwise.

In conclusion, prefabricating the piping system and the electric rough-ins with a precast concrete wall will be very advantageous for the overall success of the project especially that it will achieve the main goal of reducing congestion in addition to saving time, increasing quality, reducing waste which will further improve the development and progress of the project. However, the implication of all these benefits would be an increase in price. Since there is no urgent need for schedule acceleration and since the idea of prefabrication was to search for other great alternative to the current good method and no as a result of an issue, I would recommend that this change would not be implemented since there is no strong need for the benefits of prefabrication at this cost.

11.0 Final Recommendation and Conclusion

The work on this report has been a part of the Senior Thesis Capstone Project under the Department of Architectural Engineering in Penn State. This project took place over the course of both the fall and spring semesters proving a better understanding of the overall building process, methods, various systems and problems that were faced. The research conducted and the conclusion that were drawn are only meant to serve educational purposes and the goals of the Senior Thesis Capstone Project and are in no way criticizing or perceiving inefficiencies in the outstanding work of the entire project team.

Four proposed analyses have been discussed in this report and they are as follows:

Analysis 1: BIM application – Energy Analysis

After conducting this analysis, it can be concluded that incorporating Energy analysis into any project is very beneficial to the building project from an energy perspective. Basically, if a project is utilizing BIM, then it would be very easy and very beneficial for the building project to make use of this feature. The energy analysis could be performed at first as a generic model to have a general understanding of the energy consumption for this area and location. And then, as the design progresses, the model can then be brought at any point or before any design change takes place through the use of BIM to conduct the energy analysis once again and see how the building is affected. By repeating this process through the project design, a better design with a better energy model for the building can be reaching through the use of energy reducing concepts which will eventually create more sustainable building that requires less energy and inevitably less costs.

Analysis 2: Feasibility of Incorporating Solar Photovoltaic Systems

The main reason for conducting this analysis was as a result of the high energy usage of this plant. Since reducing the energy requirements of the building is not possible since they are dependence on the process equipment, the plan would be to provide a sustainable method to input energy into the system. After conducting the analysis, incorporating Solar Photovoltaic panels into the West Fuala Plant Expansion is high recommended since it will not only provide the building with a sustainable form of energy, it will also bring in energy savings so much that the payback period for the system is within the 8^{th} year.

Analysis 3: Structural Modification to Precast Mezzanine

This analysis was performed with the aim of finding a better system than the current through the use of mass prefabrication and reduction of trades on site. Since the entire building is precast erected building with only a few area using another structural system, it would be interesting to see that using only 1 structural system would provide a better outcome.

The conclusion from this analysis is that, the precast concrete structure turn out to be heavier than the steel mezzanine as a result of the large self-weight of the precast. However, according to the cost and schedule analysis, using a precast concrete system is actually cheaper by $888,000 and is expected to take less time. In addition to benefits from cost and schedule, a precast system has many other benefits that has been explored from the aspect of logistics, transportation, less congestion on site from different trades, less contractors if only 1 structural system was used, et cetera.

Analysis 4: Bathroom prefabrication

This analysis was conducted to solve the issues of congestion in the Bathroom/locker area O in the second floor since around 11 tasks will take place in that area. The project team requested prefabrication of the piping system in the bathroom CMY walls. This analysis proposed prefabricating the entire bathroom walls along with the electric rough-ins within precast concrete units like the rest of the entire building walls, roof, and other units. Benefits from a cost and schedule perspective have been noted down in addition to the obvious benefits of prefabrication and modular construction.

12.0 Resources

"Autodesk Labs." *Autodesk Labs*. Web. 01 Apr. 2012. <http://labs.autodesk.com/>.

"Harrisburg, Pennsylvania Climate Guide to the Average Weather & Temperatures with Graphs Elucidating Sunshine and Rainfall Data & Information about Wind Speeds & Humidity:." *Harrisburg, Pennsylvania Climate Information*. Web. 01 Apr. 2012. <http://www.climatetemp.info/usa/harrisburg-pennsylvania.html>.

"National Renewable Energy Laboratory (NREL) Home Page." *National Renewable Energy Laboratory (NREL) Home Page*. Web. 01 Apr. 2012. <http://www.nrel.gov/>.

"Off Grid (Stand Alone)Â Remote Solar and Wind Power Systems." *Off Grid Power Systems*. Web. 01 Apr. 2012. <http://wirefreedirect.com/off_grid_solar_wind_power_system.asp>.

"Passive Solar Heating." *WBDG*. Web. 01 Apr. 2012. <http://www.wbdg.org/resources/psheating.php>.

"Pennsylvania." *DSIRE USA*. Web. 01 Apr. 2012. <http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=PA37F>.

"Solar Electricity Basics." Web. 01 Apr. 2012. <http://homepower.com/basics/solar/>.

"Solar Panel and Complete Systems for Commercial, Government and Utility Solar Electric Power Supply." *Solar Electric Supply*. Web. 01 Apr. 2012. <http://solarelectricsupply.com/systems/commercial/index.html>.

"Solar Sky Grid-tie System: 80 Astronergy Solar Modules and Two Fronius IG Plus V 10.0-1 Gridtie Inverters." *19,200-watt Gridtied Solar System with 80 Astronergy Solar Panels*. Web. 01 Apr. 2012. <http://www.wholesalesolar.com/system/80-astronergy-solar-sky-grid-tie-solar-power-system.html>.

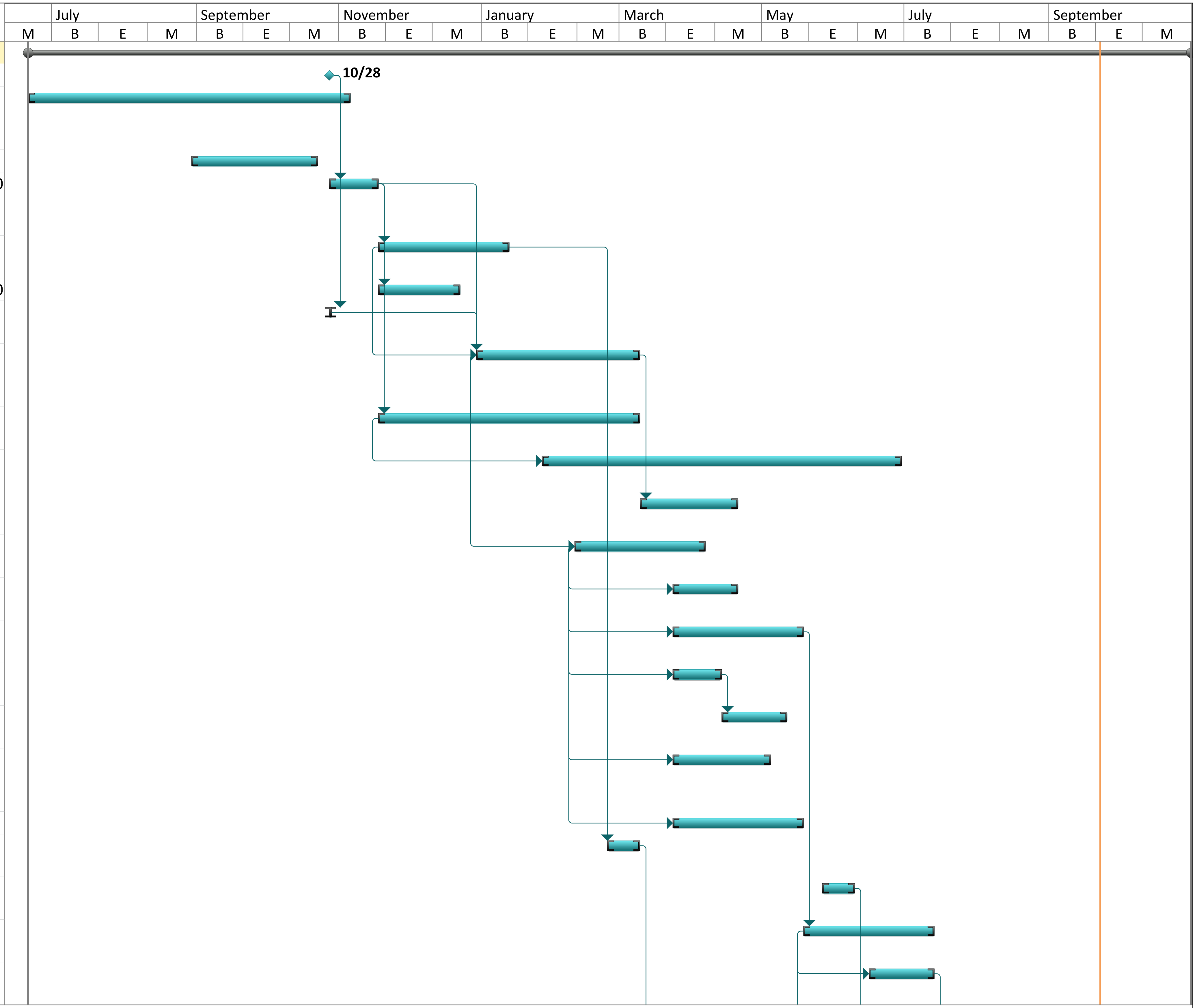
"Solar Sunlight Hours." *Using Sunlight to Make Solar Power from Solar Panels*. Web. 01 Apr. 2012. <http://www.longtermsolar.com/solar-sunlight-hours/>.

"State SREC Markets." *SRECTrade*. Web. 01 Apr. 2012. <http://srectrade.com/pennsylvania_srec.php>.

Appendix A

Project Schedule

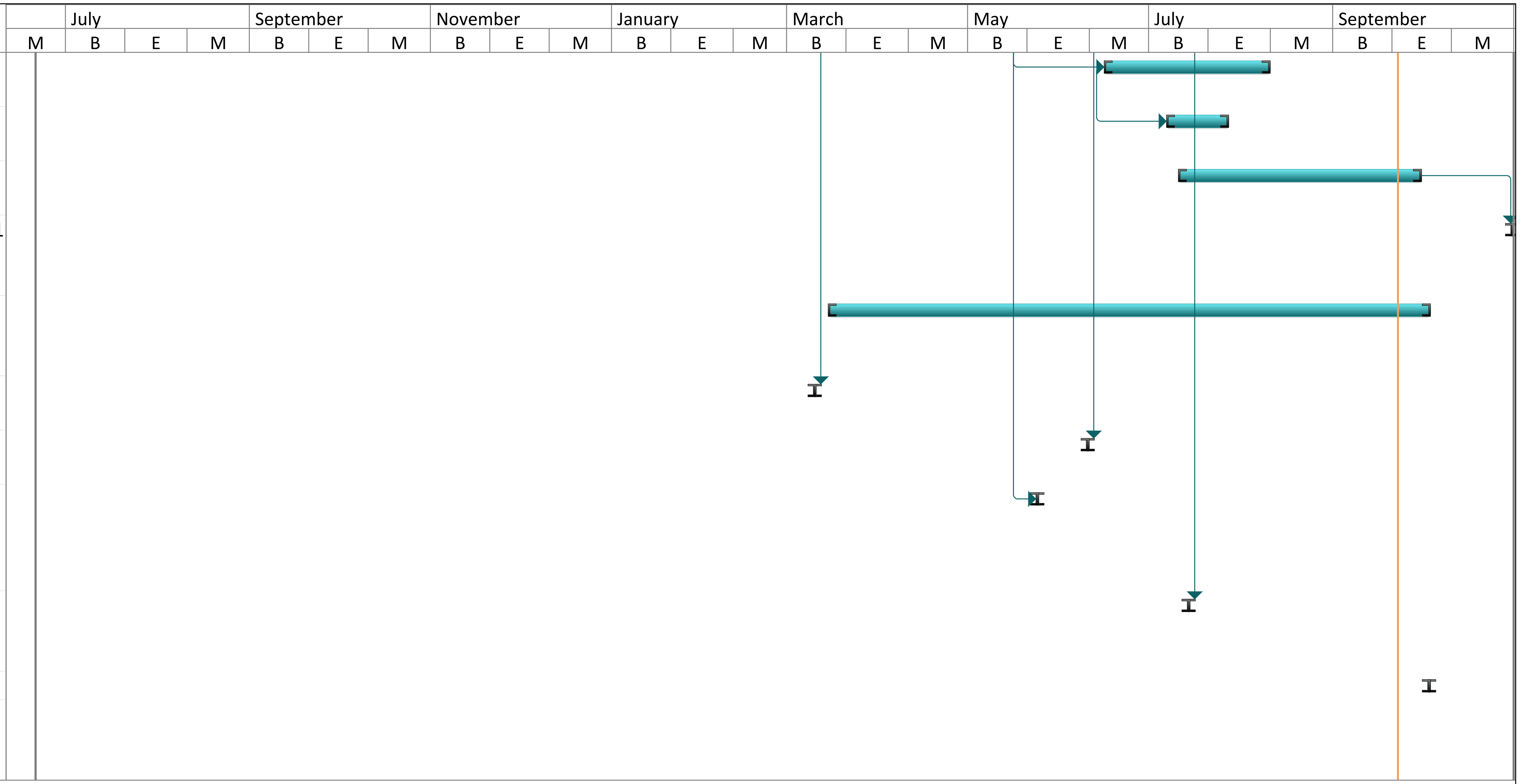
ID	Task Name	Duration	Start	Finish
	Task Mode: Manually Schedu	**145d**	**Mon 6/21/10**	**Mon 10/31/11**
1	Obtain Permit	0 days	Thu 10/28/10	Thu 10/28/10
2	Sitework/Roads Paving Retaining Walls/Rail	100 days	Mon 6/21/10	Fri 11/5/10
3	Establish Building Pad	40 days	Mon 8/30/10	Fri 10/22/10
4	Foundation Excavation/Pour Spread Footing	15 days	Thu 10/28/10	Wed 11/17/10
5	Foundation Walls Form and Pour	40 days	Thu 11/18/10	Wed 1/12/11
6	Underslab Utilities	25 days	Thu 11/18/10	Wed 12/22/10
7	Begin Building Construction Shell	1 day	Thu 10/28/10	Thu 10/28/10
8	Structural Framing Erect/ include Mezzanine	50 days	Thu 12/30/10	Wed 3/9/11
9	Construct New utility Building	80 days	Thu 11/18/10	Wed 3/9/11
10	Install Utility Equipment and Pipe	110 days	Thu 1/27/11	Wed 6/29/11
11	Install 2 Hr Separation Wall/Tilt Up	30 days	Thu 3/10/11	Wed 4/20/11
12	Install Decking and Liner Panel	40 days	Thu 2/10/11	Wed 4/6/11
13	Insulated Metal Wall Panel System	20 days	Thu 3/24/11	Wed 4/20/11
14	Install Single Ply Membrane Roofing	40 days	Thu 3/24/11	Wed 5/18/11
15	Install Supports for Roof Top Equipment	15 days	Thu 3/24/11	Wed 4/13/11
16	Set Roof Top Equipment	20 days	Thu 4/14/11	Wed 5/11/11
17	Interior Air Dist/Ductwork & Insulation	30 days	Thu 3/24/11	Wed 5/4/11
18	Sprink Piping & Lighting	40 days	Thu 3/24/11	Wed 5/18/11
19	Silo & Basement concrete	10 days	Thu 2/24/11	Wed 3/9/11
20	Place Mezzanine Concrete	10 days	Fri 5/27/11	Thu 6/9/11
21	Place Concrete Slab on Grade	40 days	Thu 5/19/11	Wed 7/13/11
22	Acid Brick Flooring Install Syrup Area	20 days	Thu 6/16/11	Wed 7/13/11



Project: Schedule tech 1
Date: Fri 9/23/11

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

ID	Task Name	Duration	Start	Finish
23	Install interior Walls & Doors	40 days	Thu 6/16/11	Wed 8/10/11
24	Install Misc Metal Guarding	15 days	Thu 7/7/11	Wed 7/27/11
25	Utility Equipment Start Up	60 days	Mon 7/11/11	Fri 9/30/11
26	Building substaintially complete	1 day	Mon 10/31/11	Mon 10/31/11
27	**WF Building Construction Milestones**	145 days	Tue 3/15/11	Mon 10/3/11
28	Silo & Basement concrete (Complete)	1 day	Thu 3/10/11	Thu 3/10/11
29	Mezzanine concrete (comeplete)	1 day	Fri 6/10/11	Fri 6/10/11
30	Complete concrete placement slab on grade (Reserve syrup Area)	1 day	Tue 5/24/11	Tue 5/24/11
31	Acid Brick Footing (comeplete for syrup install)	1 day	Thu 7/14/11	Thu 7/14/11
32	Utilities Available	1 day	Mon 10/3/11	Mon 10/3/11
34				



Project: Schedule tech 1
Date: Fri 9/23/11

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

Appendix B

Detailed Structural System Estimate

CONTINUOUS FOOTING	Wall Footing Thickness	Wall Footing Width	Perimeter	Total Volume (CUFT)	Total Volume (CY)
Zone A (A,B,C,D,E,F)	1	6	1041	6246	231.3333333
Zone B (G,H,I,J)	2	10	1474	29480	1091.851852
TOTAL				35726	1323.185185

FOUNDATION WALL	Thickness	Height	Perimeter	Total Volume (CUFT)	Total Volume (CY)
Zone A	1	4.5	1041	4684.5	173.5
Zone B	1.5	28.67	1474	63389.37	2347.754444
TOTAL				68073.87	2521.254444

PRECAST WALLS	perimeter	width	Count	Height	SF
Exterior Walls	2515	12	209.5833333	32.5	81737.5

S.O.G. FOUNDATION	Thickness	Area	Total Volume (CUFT)	Total Volume (CY)
Zone A	0.50	178559	89279.5	3306.648148
Zone B	0.67	60822	40548	1501.777778
TOTAL			129827.5	4808.425926

PRECAST Double Tee Count	Area G	Area H	Mezz B	Roof Overall
Length = 32'	48	72	0	0
length = 64'	0	0	15	255

CONCRETE TOPPING (S.O.G.)	Thickness	Area	Total Volume (CUFT)	Total Volume (CY)
Mezz	0.25	31882	7970.5	295.2037037
Zone B	0.33333	49765	16588.16745	614.3765722
TOTAL			24558.66745	909.5802759

Concrete on composite Slab	thickness	area	Total Volume (CUFT)	Total Volume (CY)
Area I	0.5	11650	5825	215.7407407
Area J	0.5	49762	24881	921.5185185
Mezz B	0.5	11833	5916.5	219.1296296
TOTAL			36622.5	1356.388889

INTERIOR PRECAST COLUMNS	1 per 32'x32' = 1024 SQFT			
	Area	Typical Bay = 32' x 32'	PRECAST COLUMN Count	Rounded
Zone A - First Floor	178559	1024	174.3740234	175
Zone B - First Floor	60822	1024	59.39648438	60
Zone B - basement	60822	1024	59.39648438	60

SPREAD FOOTINGS	1 per 32'x32' = 1024 SQFT			
	Volume of Footing	Like Precast column Count	Total Volume (CUFT)	Total Volume (CY)
Zone A	288	175	50400	1866.666667
Zone B	588	60	35280	1306.666667
TOTAL			85680	3173.333333

STEEL MEMBERS					
Beam Type	Count	Length	Total Length	Weight	Total Weight
HSS 10X6X1/4	23	16	368	25.82	9501.76
HSS 12x12x3/8	23	30	690	78.52	54178.8
HSS 12X12X5/16	2	30	60	65.87	3952.2
HSS 20X12X1/2	52	32	4894	103.3	505550.2
HSS 20X12X5/8	20	32	640	123.72	79180.8
HSS 28X24X1/2	3	32	448	169.89	76110.72
HSS 32X24X5/8	1	32	96	225.8	21676.8
W 12X26	4	25	100	26	2600
W 14x109	28	30	840	109	91560
W 21X44	89	25	120	44	5280
W 24X55	4	25	100	55	5500
W 27X84	7	25	175	84	14700
W 30X108			378	108	40824
W 30X90	3	20	60	90	5400
W 33X118	8	25	200	118	23600
W 36X170	2	32	64	170	10880
TOTAL WEIGHT W					200344
TOTAL WEIGHT HSS					750151.28

TOTAL Cast-In Place Concrete (CY)	**380488.5375**
TOTAL PRECAST COLUMN COUNT	295
TOTAL PRECAST DOUBE T COUNT (32')	120
TOTAL PRECAST DOUBE T COUNT (64')	270

STEEL COST SUMMARY		
	Weight	cost
W	200344	292600
HSS	750151	1095587
Ratio	1	1.46
TOTAL COST		1,388,187.00

CONCRETE COST SUMMARY	
Precast Cost	4,744,507.00
CIP cost	4,905,177.00
TOTAL CONCRETE	9,649,684.00

SYSTEM COST	Estimated	Actual
Concrete	9,649,684	12,735,300.00
Metals	1,388,187	4,631,919.00
TOTAL COST	11,037,871	17,367,219.00

Appendix C

Square Foot Cost Estimate Report

Square Foot Cost Estimate Report

Estimate Name:	**Untitled**	
Building Type:	**Factory, 1 Story with Concrete Block / Bearing Walls**	
Location:	**National Average**	
Story Count:	**1**	
Story Height (L.F.):	**33**	
Floor Area (S.F.):	**324403**	
Labor Type:	**Union**	
Basement Included:	**Yes**	
Data Release:	**Year 2008 Quarter 1**	Costs are derived from a building model with basic components.
Cost Per Square Foot:	**$98.31**	Scope differences and market conditions can cause costs to vary significantly.
Building Cost:	**$31,892,000**	**Parameters are not within the ranges recommended by RSMeans.**

		% of Total	Cost Per S.F.	Cost
A Substructure		**11.90%**	**$8.75**	**$2,839,000**
A1010	**Standard Foundations**		**$0.47**	**$152,000**
	KSF, 12" deep x 24" wide			
	4' - 6" square x 15" deep			
A1030	**Slab on Grade**		**$4.61**	**$1,495,500**
	Slab on grade, 4" thick, non industrial, reinforced			
A2010	**Basement Excavation**		**$2.98**	**$966,500**
	storage			
A2020	**Basement Walls**		**$0.69**	**$225,000**
	thick			
B Shell		**35.90%**	**$26.36**	**$8,550,500**
B1010	**Floor Construction**		**$13.03**	**$4,227,000**
	height, 142 lbs/LF, 4000PSI			
	15'x15' bay, 75 PSF superimposed load, 153 PSF total load			
B1020	**Roof Construction**		**$6.67**	**$2,164,000**
	wall, 40'x40' bay, 40 PSF superimposed load, 40.5" deep, 61 PSF total load			
B2010	**Exterior Walls**		**$0.53**	**$173,500**
	Concrete block (CMU) wall, lightweight, hollow, 4 x 8 x 16, 85 PCF			
B2020	**Exterior Windows**		**$0.64**	**$208,000**
	Windows, aluminum, sliding, insulated glass, 8' x 4'			
B2030	**Exterior Doors**		**$1.00**	**$323,500**
	hardware, 6'-0" x 10'-0" opening			
	0" opening			
	opening			
B3010	**Roof Coverings**		**$4.17**	**$1,353,000**
	mopped			
	Insulation, rigid, roof deck, composite with 2" EPS, 1" perlite			
	Roof edges, aluminum, duranodic, .050" thick, 6" face			
	Flashing, aluminum, no backing sides, .019"			
	Gravel stop, aluminum, extruded, 4", mill finish, .050" thick			
B3020	**Roof Openings**		**$0.31**	**$101,500**
	steel, 165 lbs			
	operator			
C Interiors		**7.80%**	**$5.70**	**$1,848,500**

C1010	**Partitions**		**$1.51**	**$489,000**
	Partition, concrete block, 6" thick			
C1020	**Interior Doors**		**$1.40**	**$455,500**
	0" x 7'-0" x 1-3/8"			
C1030	**Fittings**		**$1.07**	**$348,500**
	Toilet partitions, cubicles, ceiling hung, stainless steel			
C3010	**Wall Finishes**		**$0.82**	**$266,500**
	2 coats paint on masonry with block filler			
	Painting, masonry or concrete, latex, brushwork, primer & 2 coats			
C3020	**Floor Finishes**		**$0.31**	**$99,000**
	Vinyl, composition tile, maximum			
C3030	**Ceiling Finishes**		**$0.59**	**$190,000**
	channel grid, suspended support			
D Services		**44.50%**	**$32.70**	**$10,606,500**
D2010	**Plumbing Fixtures**		**$2.94**	**$954,000**
	Water closet, vitreous china, bowl only with flush valve, wall hung			
	Urinal, vitreous china, stall type			
	Lavatory w/trim, vanity top, PE on CI, 19" x 16" oval			
	Kitchen sink w/trim, countertop, stainless steel, 33" x 22" double bowl			
	18"			
	Shower, stall, baked enamel, terrazzo receptor, 36" square			
	Shower, stall, fiberglass 1 piece, three walls, 32" square			
	Water cooler, electric, floor mounted, dual height, 14.3 GPH			
D2020	**Domestic Water Distribution**		**$0.04**	**$13,000**
	Gas fired water heater, commercial, 100< F rise, 115 MBH input, 110 GPH			
D2040	**Rain Water Drainage**		**$0.06**	**$18,000**
	Roof drain, CI, soil,single hub, 5" diam, 10' high			
	Roof drain, CI, soil,single hub, 5" diam, for each additional foot add			
D3010	**Energy Supply**		**$7.85**	**$2,548,000**
	water, 10,000 SF bldg,100,000 CF, total, 2 floors			
D3030	**Cooling Generating Systems**		**$9.85**	**$3,194,000**
	ton			
D4010	**Sprinklers**		**$3.30**	**$1,070,500**
	Wet pipe sprinkler systems, steel, ordinary hazard, 1 floor, 50,000 SF			
D5010	**Electrical Service/Distribution**		**$0.12**	**$37,500**
	phase, 4 wire, 120/208 V, 600 A			
	Feeder installation 600 V, including RGS conduit and XHHW wire, 600 A			
	Switchgear installation, incl switchboard, panels & circuit breaker, 600 A			
D5020	**Lighting and Branch Wiring**		**$8.16**	**$2,647,000**
	Receptacles incl plate, box, conduit, wire, 2.5 per 1000 SF, .3 watts per SF			
	Miscellaneous power, 1 watt			
	Central air conditioning power, 4 watts			
	HID fixture, 8'-10' above work plane, 100 FC, type C, 8 fixtures per 1800 SF			
D5030	**Communications and Security**		**$0.38**	**$124,500**
	wire, fire detection systems, 25 detectors			
E Equipment & Furnishings		**0.00%**	**$0.00**	**$0**
E1090	**Other Equipment**		**$0.00**	**$0**
F Special Construction		**0.00%**	**$0.00**	**$0**
G Building Sitework		**0.00%**	**$0.00**	**$0**

SubTotal	**100%**	**$73.50**	**$23,844,500**
Contractor Fees (General Conditions,Overhead,Profit)	**25.00%**	**$18.38**	**$5,961,000**
Architectural Fees	**7.00%**	**$6.43**	**$2,086,500**
User Fees	**0.00%**	**$0.00**	**$0**
Total Building Cost		**$98.31**	**$31,892,000**

Appendix D

Existing Conditions Plan

Existing Conditions Site Plan
West Fuala Plant Expansion
Abu Dhabi, PA

Appendix D

Jaafar Al Aidaroos
09/05/2011

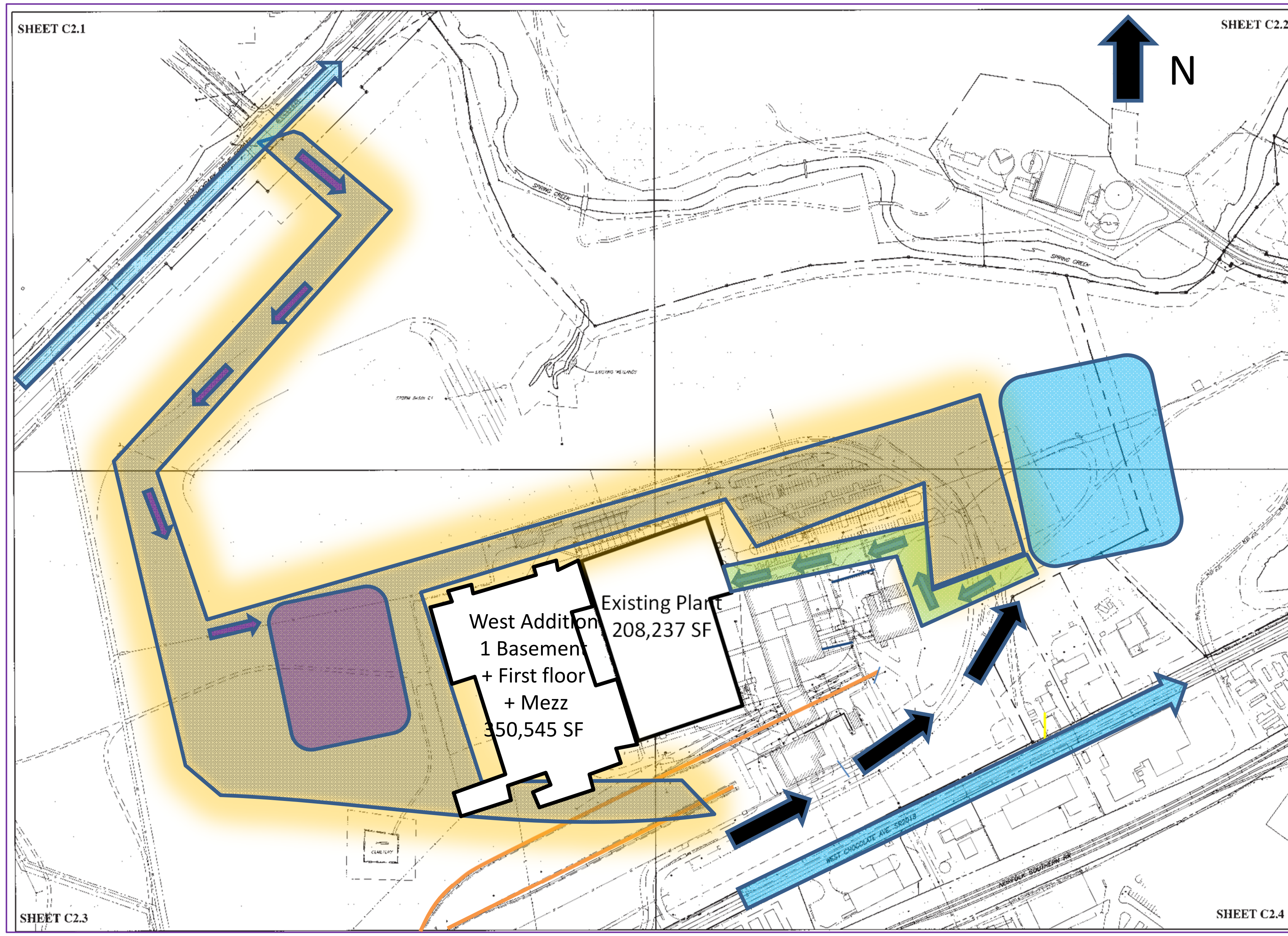
Existing Conditions Site Plan
West Fuala Plant Expansion
Abu Dhabi, PA

Appendix D

Jaafar Al Aidaroos
09/05/2011

Legend

- Normal Vehicular Traffic
- Existing traffic for factory workers
- New pedestrians traffic for factory works from Lot
- New path for construction vehicles
- New Road
- Lighting
- Existing Structure
- Construction personnel Parking Lot
- New Factory workers Parking lot



West Fuala Plant Expansion
Abu Dhabi, PA

Existing Condition Site Plan

09/05/2011

Jaafar Al Aidaroos CM

OVERALL SITE LIGHTING PLAN

Appendix E

Site Layout Planning

Existing Conditions Site Plan
West Fuala Plant Expansion
Abu Dhabi, PA

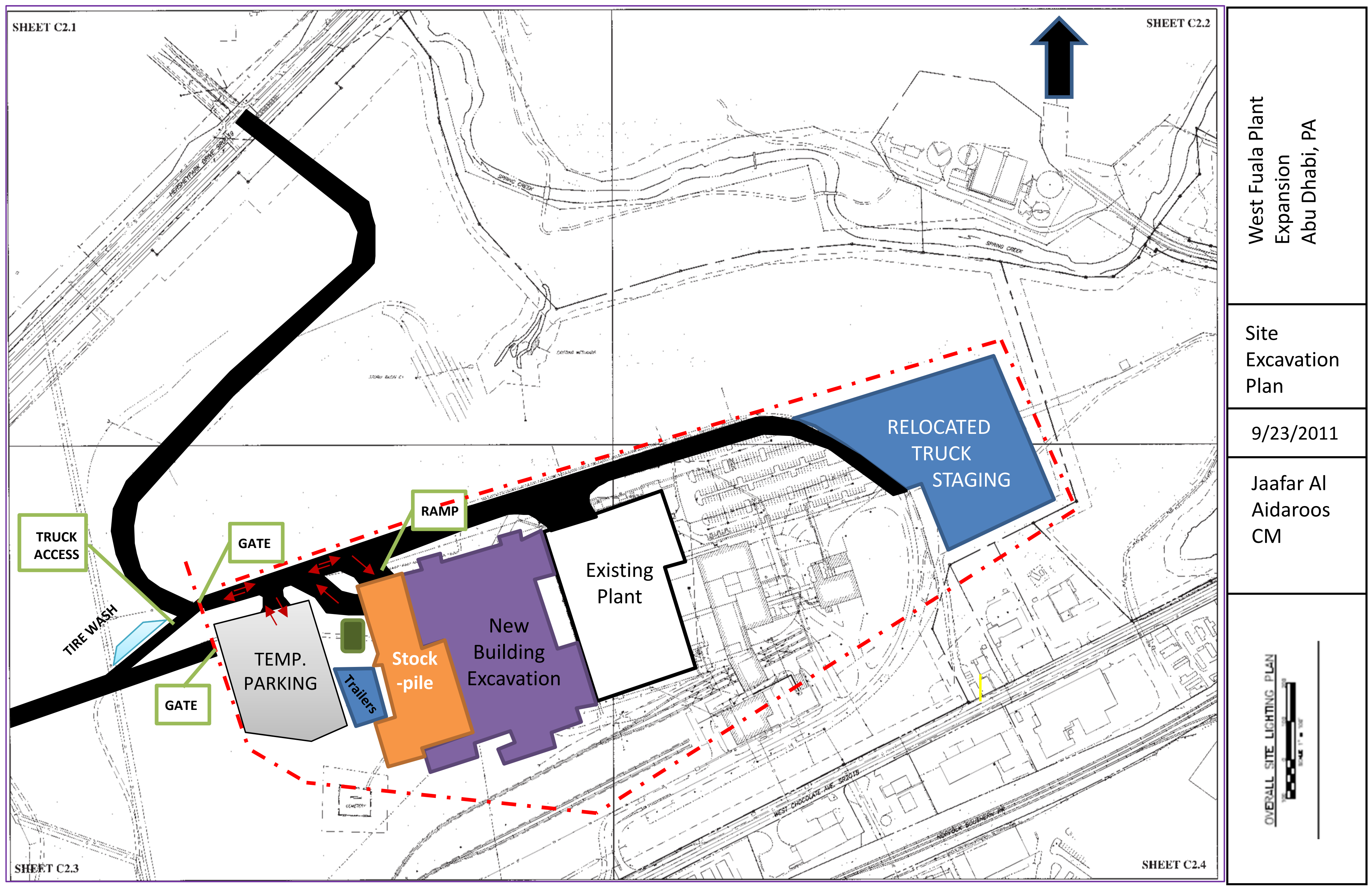
Appendix E

Jaafar Al Aidaroos
09/23/2011

Legend

DUMPSTER

FENCE



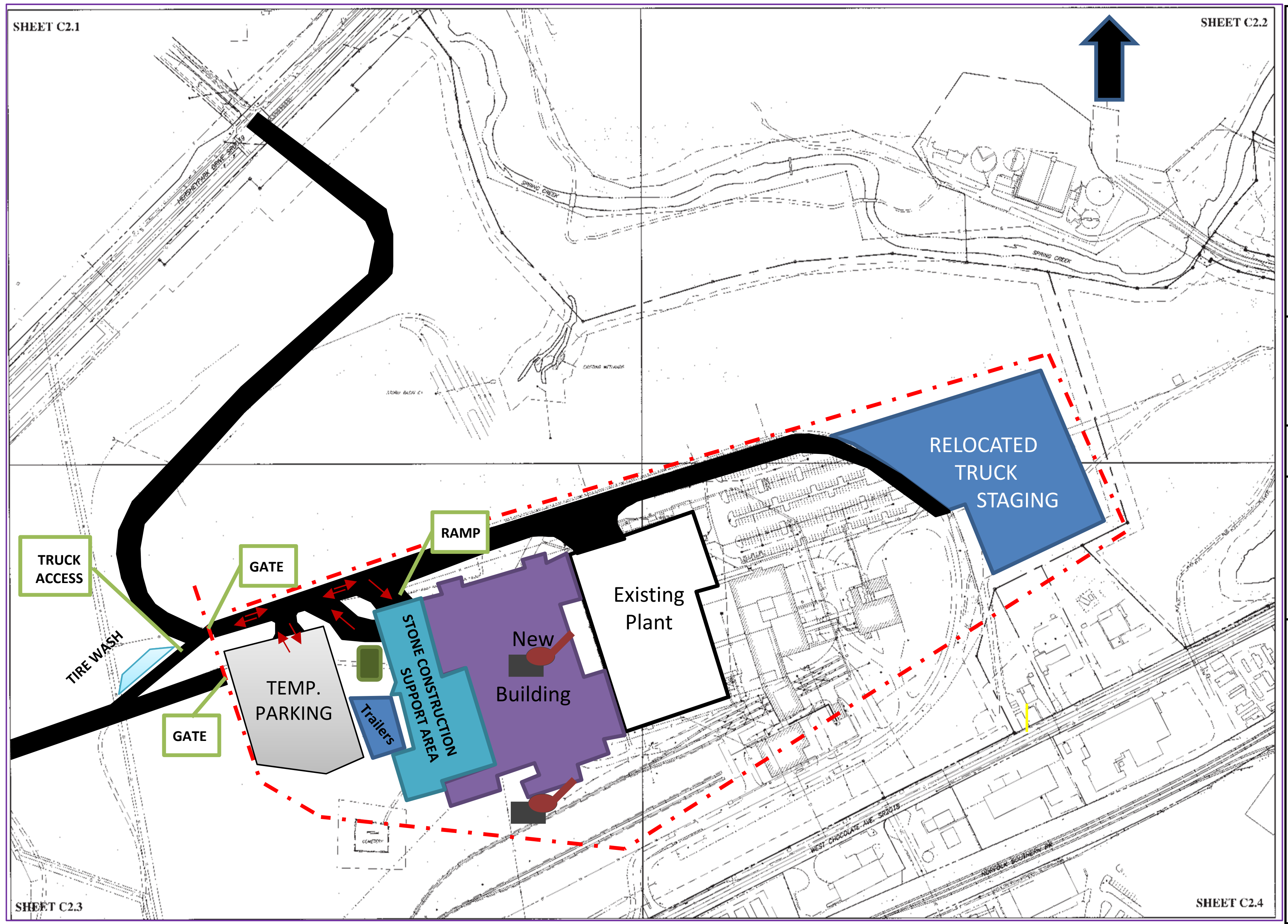
Existing Conditions Site Plan
West Fuala Plant Expansion
Abu Dhabi, PA

Appendix E

Jaafar Al Aidaroos
09/23/2011

Legend

- DUMPSTER
- FENCE
- CRANE



West Fuala Plant Expansion Abu Dhabi, PA
Superstructure plan
9/23/2011
Jaafar Al Aidaroos CM
OVERALL SITE LIGHTING PLAN

Existing Conditions Site Plan
West Fuala Plant Expansion
Abu Dhabi, PA

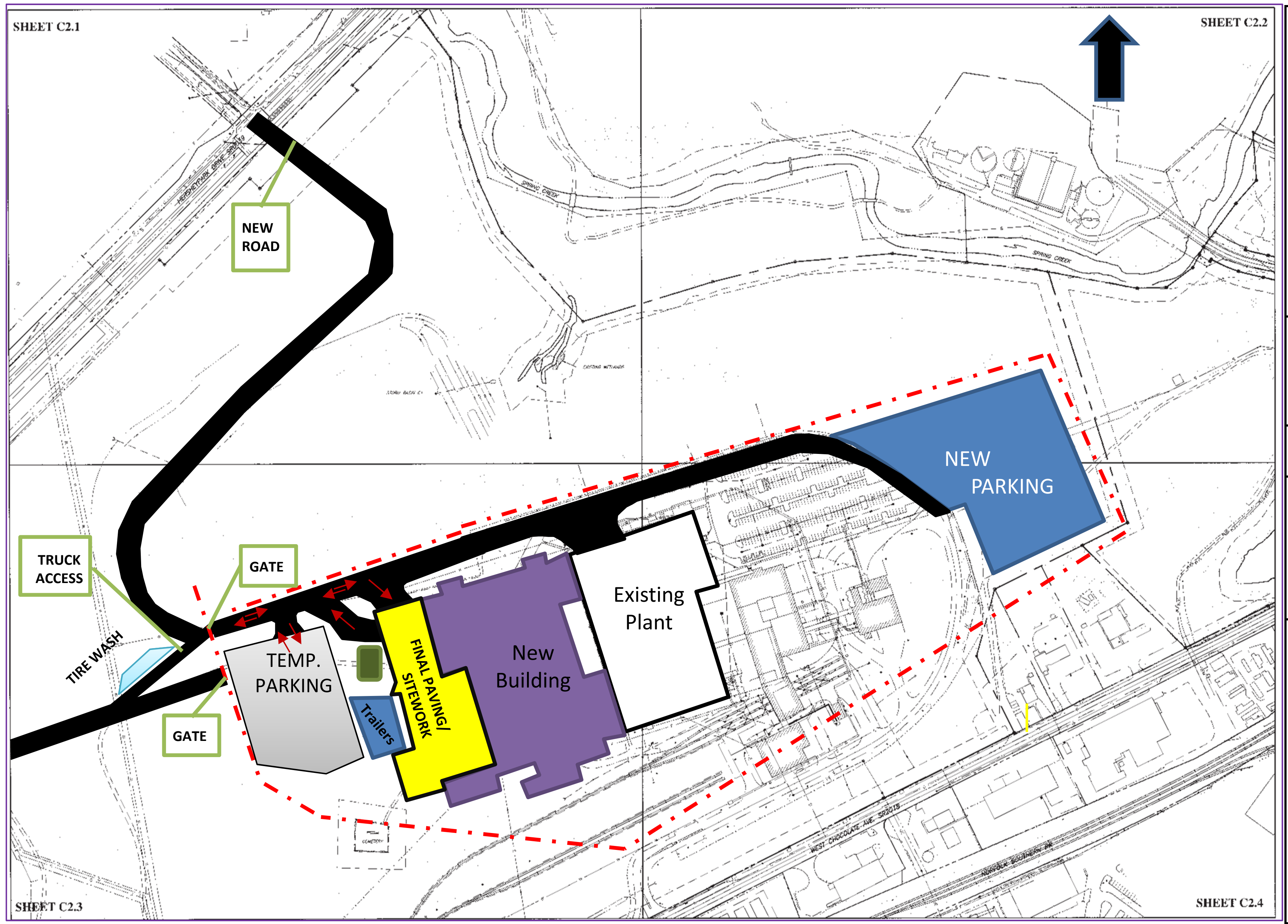
Appendix E

Jaafar Al Aidaroos
09/23/2011

Legend

DUMPSTER

FENCE

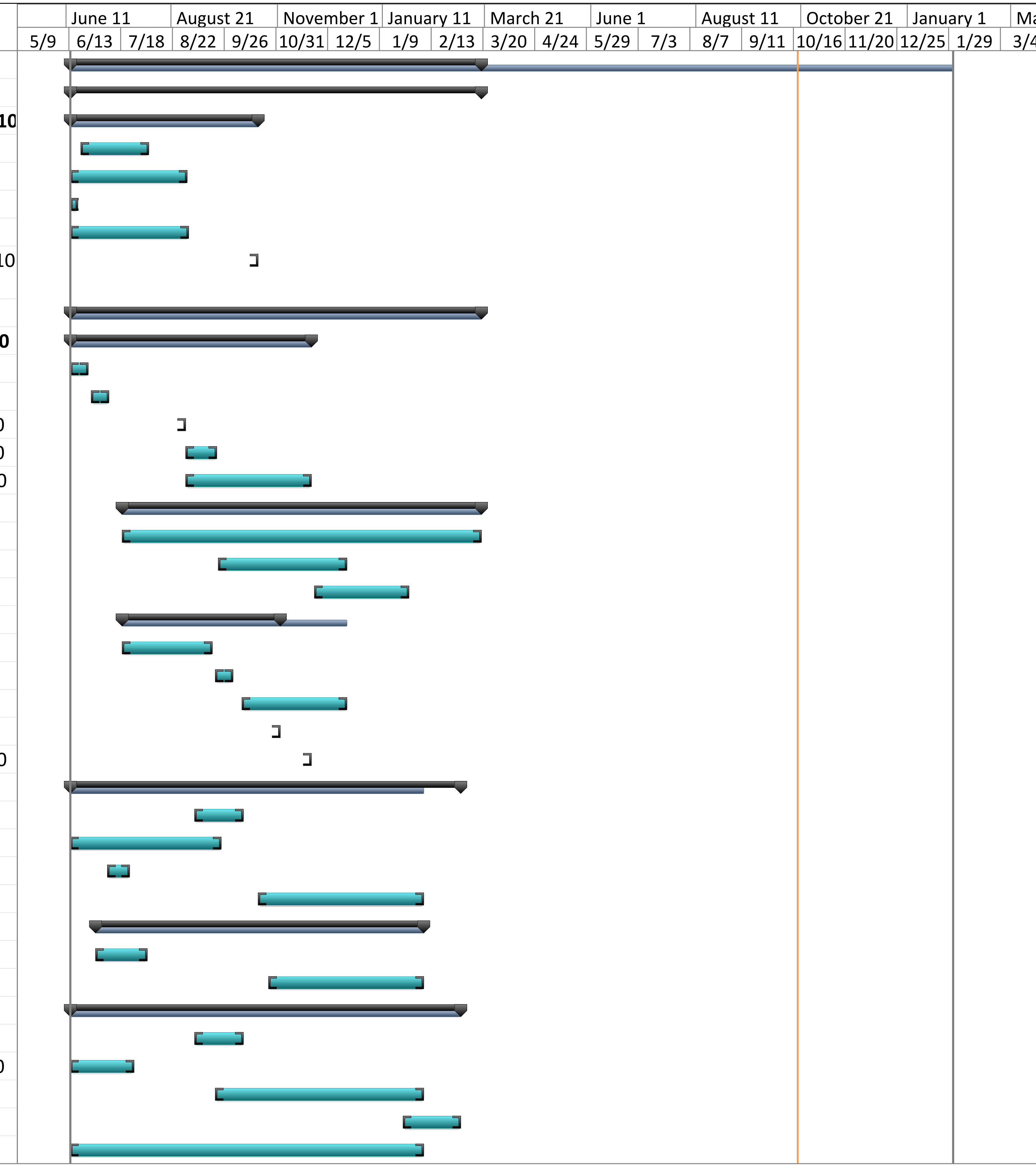


West Fuala Plant Expansion Abu Dhabi, PA
Finishing Plan
9/23/2011
Jaafar Al Aidaroos CM
OVERALL SITE LIGHTING PLAN

Appendix F

Detailed Project Schedule

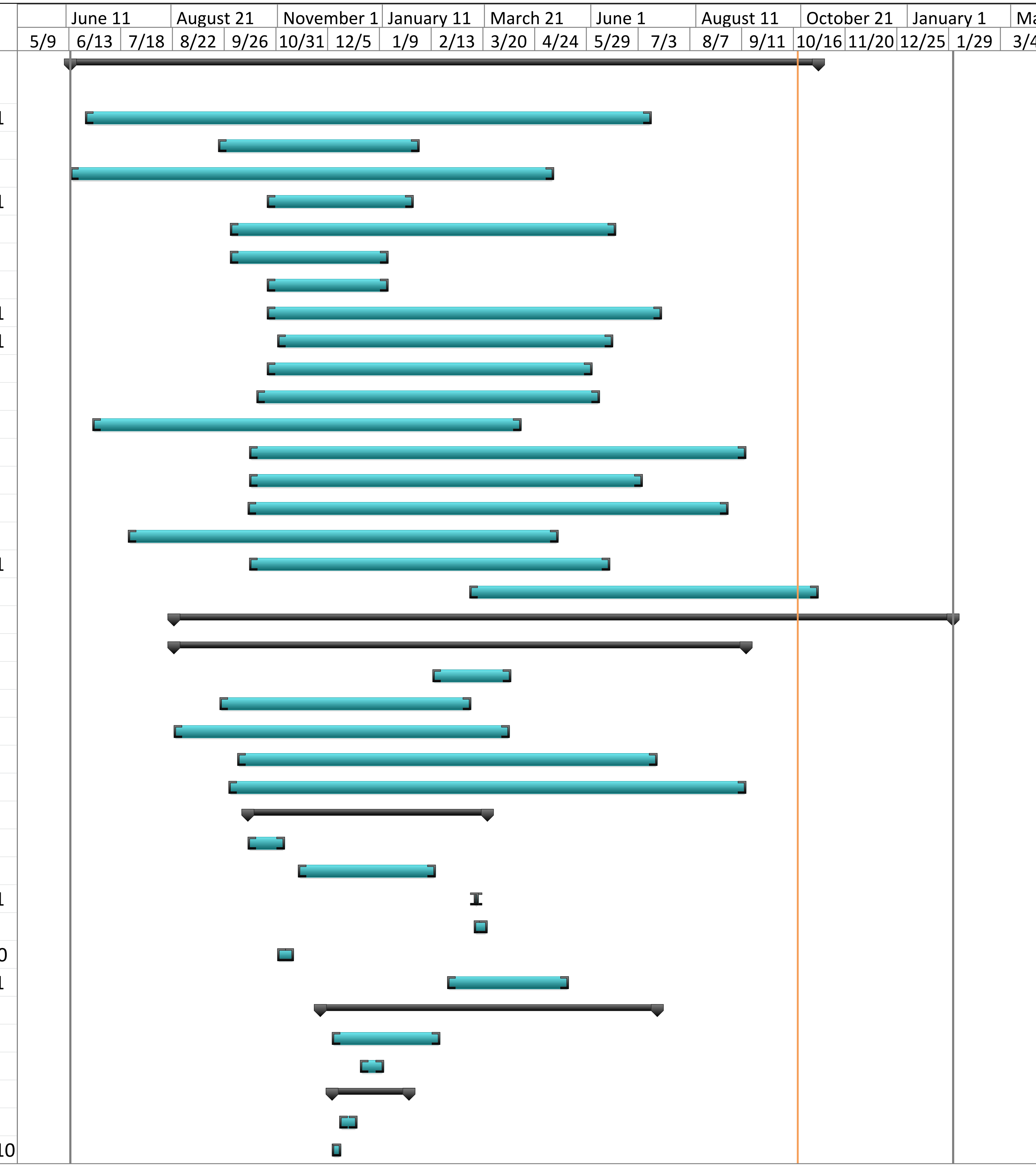
ID		Task Name	Duration	Start	Finish
1		**WEST FUALA PLANT EXPANSION**	**200 days?**	**Mon 6/14/10**	**Fri 3/18/11**
2		**Deisgn Development**	**200 days?**	**Mon 6/14/10**	**Fri 3/18/11**
3		**Fuala Design information & Approvals**	**91 days?**	**Mon 6/14/10**	**Mon 10/18/10**
4		Geotechnical Report, Preliminary and Final	34 days	Mon 6/21/10	Thu 8/5/10
5		Provide Final Site Construction/Bid Drawings	57 days	Mon 6/14/10	Tue 8/31/10
6		Provide exisiting building Drawings	5 days	Mon 6/14/10	Fri 6/18/10
7		Finalize & Sign-off on Floor plans	58 days	Mon 6/14/10	Wed 9/1/10
8		Approval of Design & puchase of Foundation, Mechanical, FP & Electrical systems			Mon 10/18/10
9		**Nutec Design Document Development & Approvals**	**200 days**	**Mon 6/14/10**	**Fri 3/18/11**
10		**Precast Structural Design**	**117 days**	**Mon 6/14/10**	**Tue 11/23/10**
11		Prepare Precast performance bid package	10 days	Mon 6/14/10	Fri 6/25/10
12		Bidding	10 days	Mon 6/28/10	Fri 7/9/10
13		Award Contract			Mon 8/30/10
14		Develop Foundation Loads	15 days	Tue 8/31/10	Mon 9/20/10
15		Prepare precast shop drawings & shell permit package	61 days	Tue 8/31/10	Tue 11/23/10
16		**Architectural Design**	**175 days**	**Mon 7/19/10**	**Fri 3/18/11**
17		Finalize Plant & Syrup Floor Plans	175 days	Mon 7/19/10	Fri 3/18/11
18		Plant Shell Permit package	63 days	Wed 9/22/10	Fri 12/17/10
19		prepare Final Arch Construction Documents	46 days	Fri 11/26/10	Fri 1/28/11
20		**Structural Design**	**77 days**	**Mon 7/19/10**	**Tue 11/2/10**
21		Preliminary Foundation Design	45 days	Mon 7/19/10	Fri 9/17/10
22		Foundation Design / Precast Coordination	10 days	Mon 9/20/10	Fri 10/1/10
23		Plant Shell Permit Package	51 days	Fri 10/8/10	Fri 12/17/10
24		Issue Mezzanine Steel Bid Package			Tue 11/2/10
25		Issue UTB, silo & Rail Shed Steel bid package			Tue 11/23/10
26		**Mechanical Design**	**190 days**	**Mon 6/14/10**	**Fri 3/4/11**
27		Complete underslab piping layout	25 days	Mon 9/6/10	Fri 10/8/10
28		Validate Mecha Design Loads	74 days	Mon 6/14/10	Thu 9/23/10
29		Issue Design/build Refrigeration Systems package	11 days	Fri 7/9/10	Fri 7/23/10
30		Prepare final Mechanical Construction Documents	80 days	Tue 10/19/10	Mon 2/7/11
31		**Fire Protection Design**	**158 days**	**Thu 7/1/10**	**Mon 2/7/11**
32		Validate FP system criteria / FM requirements	25 days	Thu 7/1/10	Wed 8/4/10
33		Final Fire protection Construction Documents	75 days	Tue 10/26/10	Mon 2/7/11
34		**Electrical Design**	**190 days**	**Mon 6/14/10**	**Fri 3/4/11**
35		Complete underslab Electrical layout	25 days	Mon 9/6/10	Fri 10/8/10
36		Validate Electrical Design loads	31 days	Mon 6/14/10	Mon 7/26/10
37		Finalize Electrical Pre-purchase Package	101 days	Mon 9/20/10	Mon 2/7/11
38		Final Electrical Construction Doucments	29 days	Tue 1/25/11	Fri 3/4/11
39		Specifications	171 days	Mon 6/14/10	Mon 2/7/11



Project: Schedule 2
Date: Wed 10/19/11

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

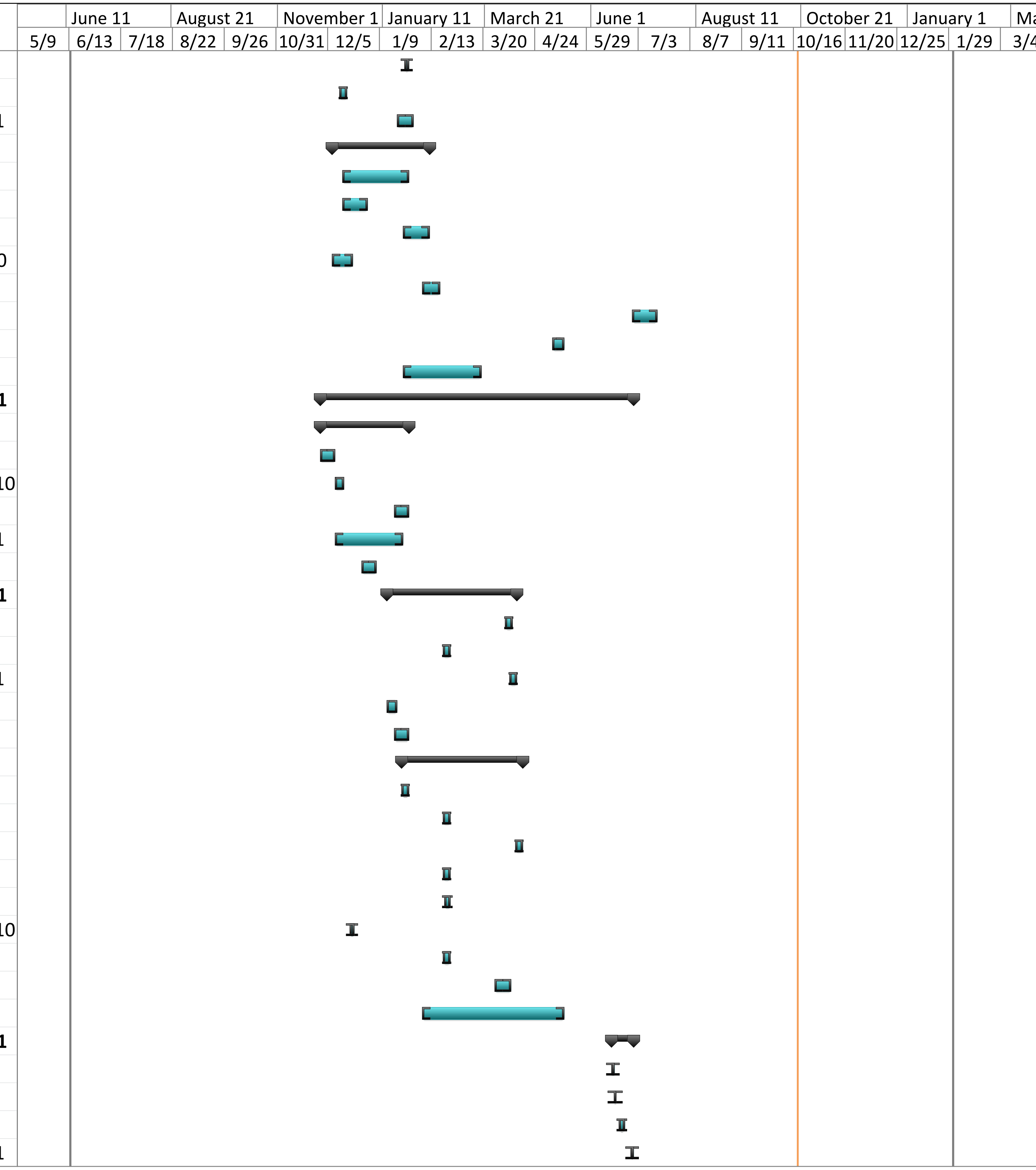
ID		Task Name	Duration	Start	Finish
40		**Package Procurement & Engineering: Develop bid package, bid, award, shop drawings, Material Fabrication & Delivery**	**362 days**	**Mon 6/14/10**	**Tue 11/1/11**
41		Earthwork & Site utility Piping	273 days	Thu 6/24/10	Mon 7/11/11
42		Foundation/ Superstructure Concrete	98 days	Wed 9/22/10	Fri 2/4/11
43		Precast Concrete	235 days	Mon 6/14/10	Fri 5/6/11
44		Roofing & Waterproofing	71 days	Mon 10/25/10	Mon 1/31/11
45		Underslab Electrical	187 days	Thu 9/30/10	Fri 6/17/11
46		Underslab Piping	77 days	Thu 9/30/10	Fri 1/14/11
47		Industrial Concrete Floors	60 days	Mon 10/25/10	Fri 1/14/11
48		Structural Steel & Metal Decking	191 days	Mon 10/25/10	Mon 7/18/11
49		Miscellaneous Metals & Stairs	163 days	Mon 11/1/10	Wed 6/15/11
50		insulated metal panels	158 days	Mon 10/25/10	Wed 6/1/11
51		Electrical Equipment Pre-purchase	166 days	Mon 10/18/10	Mon 6/6/11
52		Vertical Transportation	208 days	Tue 6/29/10	Thu 4/14/11
53		Fire protection	240 days	Wed 10/13/10	Tue 9/13/11
54		Plumbing	190 days	Wed 10/13/10	Tue 7/5/11
55		HVAC & Sheetmetal	233 days	Tue 10/12/10	Thu 9/1/11
56		Refrigeration Systems	207 days	Fri 7/23/10	Mon 5/9/11
57		Electrical Systems	174 days	Wed 10/13/10	Mon 6/13/11
58		General Construction package	168 days	Fri 3/11/11	Tue 11/1/11
59		**Construction**	**377 days**	**Mon 8/23/10**	**Tue 1/31/12**
60		**Earthwork**	**277 days**	**Mon 8/23/10**	**Tue 9/13/11**
61		Basement Foundation Wall Backfill	39 days	Mon 2/14/11	Thu 4/7/11
62		Clearing & Grubbing	122 days	Thu 9/23/10	Fri 3/11/11
63		Install Fencing	163 days	Mon 8/23/10	Wed 4/6/11
64		Remove existing parking lot paving/ curbs	204 days	Tue 10/5/10	Fri 7/15/11
65		Grade/ Stone parking lots & Access Roads	250 days	Wed 9/29/10	Tue 9/13/11
66		**Basement**	**116 days**	**Tue 10/12/10**	**Tue 3/22/11**
67		Bulk Excavation	19 days	Tue 10/12/10	Fri 11/5/10
68		Footing/ foundation excavation	67 days	Mon 11/15/10	Tue 2/15/11
69		muck-out unsuitable soil + Regrade / proof-roll subgrade	3 days	Mon 3/14/11	Wed 3/16/11
70		Place vapor barrier & stone	7 days	Mon 3/14/11	Tue 3/22/11
71		Utility building - Bulk Excavation	9 days	Mon 11/1/10	Thu 11/11/10
72		Retaining wall	58 days	Thu 2/24/11	Mon 5/16/11
73		**Foundation / Superstructure Concrete**	**164 days**	**Tue 11/30/10**	**Fri 7/15/11**
74		Basment foundation	53 days	Wed 12/8/10	Fri 2/18/11
75		36" Matt Foundations at Paste (20 - 18 / D - E)	12 days	Mon 12/27/10	Tue 1/11/11
76		**Retaining wall footing**	**38 days**	**Wed 12/8/10**	**Fri 1/28/11**
77		24' along E-line (90')	10 days	Mon 12/13/10	Fri 12/24/10
78		24' along 23-line (128')	4 days	Wed 12/8/10	Mon 12/13/10



Project: Schedule 2
Date: Wed 10/19/11

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

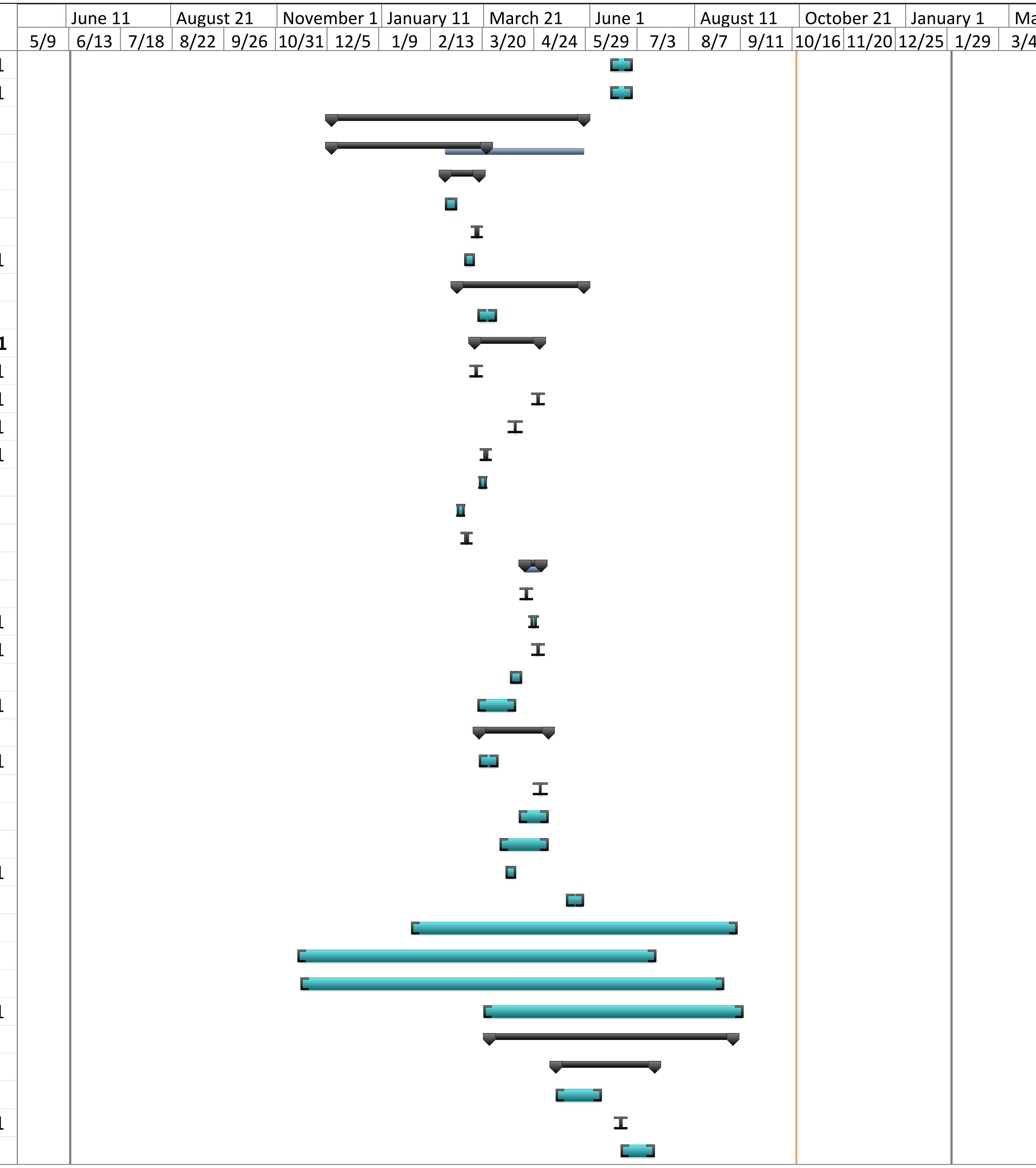
ID	Task Name	Duration	Start	Finish
79	24' along 18 @ C (26')	3 days	Wed 1/26/11	Fri 1/28/11
80	10' along A/1a (100')	5 days	Mon 12/13/10	Fri 12/17/10
81	18" Matt Foundation at Link (17-18 / A-C)	7 days	Fri 1/21/11	Mon 1/31/11
82	**Basement Foundation Walls**	**48 days**	**Wed 12/8/10**	**Fri 2/11/11**
83	along E-line (320')	33 days	Wed 12/15/10	Fri 1/28/11
84	along 23-line (128')	13 days	Wed 12/15/10	Fri 12/31/10
85	along 18 & C (126')	14 days	Tue 1/25/11	Fri 2/11/11
86	along A/1a (224')	10 days	Wed 12/8/10	Tue 12/21/10
87	Basement Interior Footings & Pits	10 days	Mon 2/7/11	Fri 2/18/11
88	Rail Shed foundation Wall (21.5, UU, 19.5)	13 days	Wed 6/29/11	Fri 7/15/11
89	Block Loading Dock footing & Foundation Walls	6 days	Fri 5/6/11	Fri 5/13/11
90	Utility Building: Footings, Retaining Walls, Interior Footing	39 days	Tue 1/25/11	Fri 3/18/11
91	**Main Building Foundations**	**152 days**	**Tue 11/30/10**	**Wed 6/29/11**
92	**[17-24 / M-U]**	**44 days**	**Tue 11/30/10**	**Fri 1/28/11**
93	North Wall Strip & Column Footing (17-24)	8 days	Tue 11/30/10	Thu 12/9/10
94	West wall Strip & Column Footing (M-U)	4 days	Fri 12/10/10	Wed 12/15/10
95	Interior Column Footing (17-24 / M - U)	8 days	Wed 1/19/11	Fri 1/28/11
96	North Wall - Perimeter fdn wall (17 - 24)	32 days	Fri 12/10/10	Mon 1/24/11
97	West Wall - Perimeter fdn Wall (M-U)	8 days	Tue 12/28/10	Thu 1/6/11
98	**[H.9-M]**	**62 days**	**Fri 1/14/11**	**Mon 4/11/11**
99	West Wall Strip & Column Footing	5 days	Mon 4/4/11	Fri 4/8/11
100	East Wall Strip & Column Footing	5 days	Mon 2/21/11	Fri 2/25/11
101	West Wall - Perimeter fdn Wall	3 days	Thu 4/7/11	Mon 4/11/11
102	East Wall - Perimeter fdn Wall	5 days	Fri 1/14/11	Thu 1/20/11
103	Interior Column Footing	8 days	Wed 1/19/11	Fri 1/28/11
104	**[E-H.9]**	**60 days**	**Mon 1/24/11**	**Fri 4/15/11**
105	West Wall Strip & Column Footing	5 days	Mon 1/24/11	Fri 1/28/11
106	East Wall Strip & Column Footing	5 days	Mon 2/21/11	Fri 2/25/11
107	Interior Column Footing Main bldg	5 days	Mon 4/11/11	Fri 4/15/11
108	West Wall - Perimeter fdn Walls	5 days	Mon 2/21/11	Fri 2/25/11
109	East Wall - Perimeter fdn Wall	4 days	Tue 2/22/11	Fri 2/25/11
110	Link Perimeter Grade beams (Q)	3 days	Mon 12/20/10	Wed 12/22/10
111	Link Perimeter Grade beams (F)	5 days	Mon 2/21/11	Fri 2/25/11
112	Office Building Expansion Foundations	9 days	Mon 3/28/11	Thu 4/7/11
113	Foundation Wall Backfill	70 days	Mon 2/7/11	Fri 5/13/11
114	**@ 11-line: Remove , Excavate, FRP, Pour in-fill**	**11 days**	**Wed 6/15/11**	**Wed 6/29/11**
115	Sawcut/ Remove Slab	2 days	Wed 6/15/11	Thu 6/16/11
116	Excavate for foundation	1 day	Fri 6/17/11	Fri 6/17/11
117	Form, Rebar & pour Foundation	4 days	Mon 6/20/11	Thu 6/23/11
118	Pour Slab in-fill	2 days	Tue 6/28/11	Wed 6/29/11



Project: Schedule 2
Date: Wed 10/19/11

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

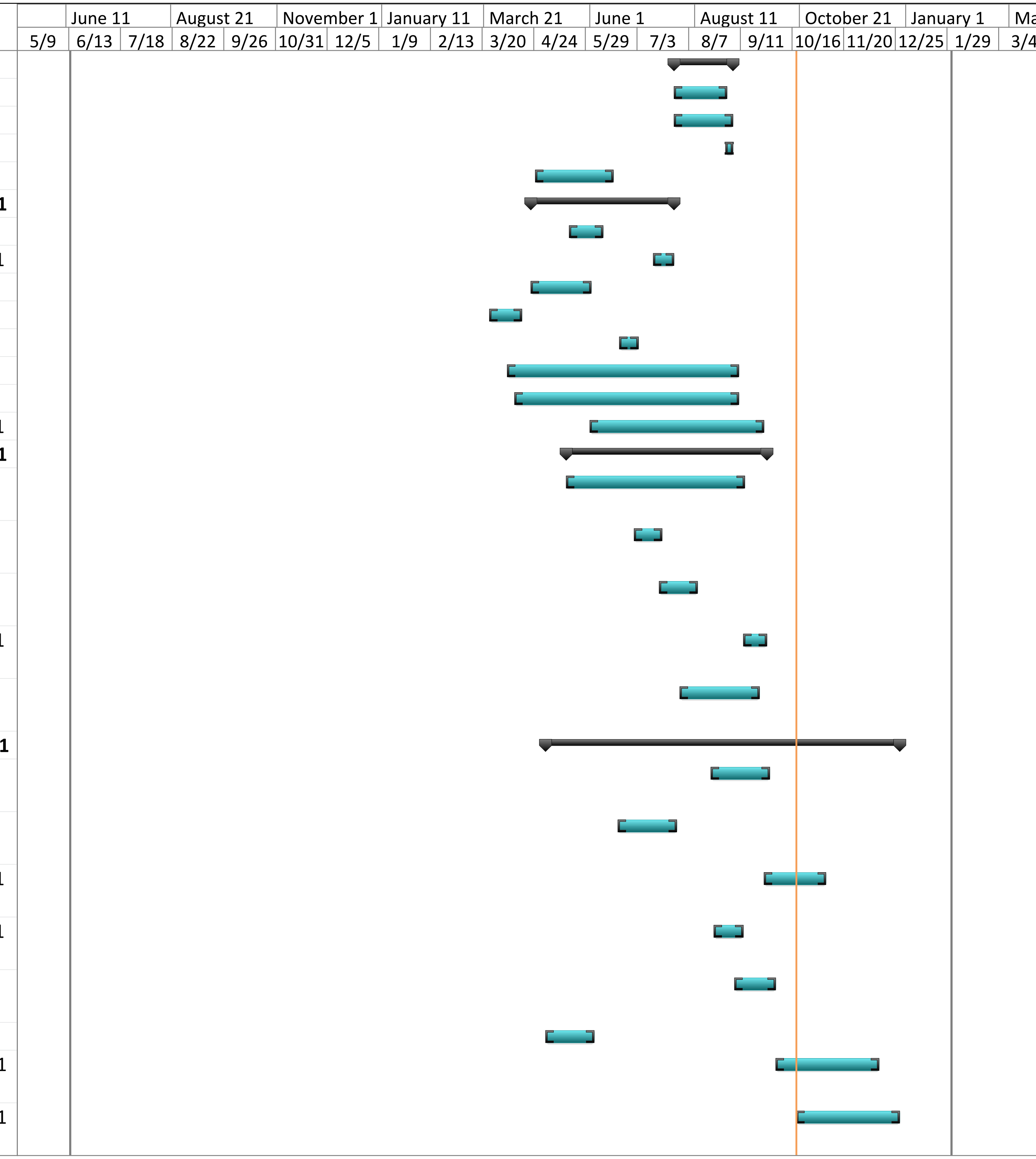
ID		Task Name	Duration	Start	Finish
119		@ 12-line: Remove , Excavate, FRP, Pour in-fill	11 days	Wed 6/15/11	Wed 6/29/11
120		@ 8-line: Remove , Excavate, FRP, Pour in-fill	11 days	Wed 6/15/11	Wed 6/29/11
121		**Precast Concrete**	**123 days**	**Wed 12/8/10**	**Fri 5/27/11**
122		**Basement / Main building Precase (A - E)**	**75 days**	**Wed 12/8/10**	**Tue 3/22/11**
123		**Basement**	**17 days**	**Wed 2/23/11**	**Thu 3/17/11**
124		Interior precast columns (29)	6 days	Wed 2/23/11	Wed 3/2/11
125		Interior Precast Walls	3 days	Tue 3/15/11	Thu 3/17/11
126		Precast Elevated Slab - over basement	5 days	Tue 3/8/11	Mon 3/14/11
127		**Main Building**	**62 days**	**Thu 3/3/11**	**Fri 5/27/11**
128		Precast Roof (2a - E & 17-23)	9 days	Thu 3/17/11	Tue 3/29/11
129		**Interior Precast Wall**	**32 days**	**Tue 3/15/11**	**Wed 4/27/11**
130		(A - E & 17 - 23)	2 days	Tue 3/15/11	Wed 3/16/11
131		(E - H.9 / 17 - 23)	2 days	Tue 4/26/11	Wed 4/27/11
132		(H.9 - P/ 17 - 23)	1 day	Mon 4/11/11	Mon 4/11/11
133		(P - U / 17 - 23)	3 days	Mon 3/21/11	Wed 3/23/11
134		Precast Walls (17 - 18 & C - E)	3 days	Fri 3/18/11	Tue 3/22/11
135		Interior Columns (18 - 23 & C - E)	3 days	Thu 3/3/11	Mon 3/7/11
136		Precast Walls (on 23 / A - E)	3 days	Tue 3/8/11	Thu 3/10/11
137		**Precast (E - H.9) "**	**9 days**	**Mon 4/18/11**	**Thu 4/28/11**
138		Walls (on 18 / E - L)	2 days	Mon 4/18/11	Tue 4/19/11
139		Interior Columns (18 - 23 & E - H.9)	2 days	Fri 4/22/11	Mon 4/25/11
140		Precast Walls (on 23 & E - H.9)	2 days	Tue 4/26/11	Wed 4/27/11
141		Precast (H.9 - P) "	6 days	Fri 4/8/11	Fri 4/15/11
142		Precast (P - U) "	18 days	Thu 3/17/11	Mon 4/11/11
143		**Precast Roof & Install RTU (18 - 23)**	**33 days**	**Fri 3/18/11**	**Tue 5/3/11**
144		(A - E)	9 days	Fri 3/18/11	Wed 3/30/11
145		(E - H.9)	1 day	Thu 4/28/11	Thu 4/28/11
146		(H.9 - P)	14 days	Thu 4/14/11	Tue 5/3/11
147		(P - U)	23 days	Fri 4/1/11	Tue 5/3/11
148		Courtyard - Precast Walls / Roof	5 days	Tue 4/5/11	Mon 4/11/11
149		Office Building Precast	10 days	Mon 5/16/11	Fri 5/27/11
150		Roofing & Waterproofing	159 days	Mon 1/31/11	Thu 9/8/11
151		Underslab Electric	175 days	Mon 11/15/10	Fri 7/15/11
152		Underslab Piping	205 days	Wed 11/17/10	Tue 8/30/11
153		Industrial Concrete Floors: Form, Rebar, Pour	126 days	Mon 3/21/11	Mon 9/12/11
154		**Structural Steel & Metal Decking**	**117 days**	**Fri 3/25/11**	**Mon 9/5/11**
155		**Silo Building**	**49 days**	**Mon 5/9/11**	**Thu 7/14/11**
156		Steel framing & Roof joists	23 days	Mon 5/9/11	Wed 6/8/11
157		Metal Decking	2 days	Tue 6/21/11	Wed 6/22/11
158		IMP Girts & Channels	17 days	Wed 6/22/11	Thu 7/14/11



Project: Schedule 2
Date: Wed 10/19/11

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

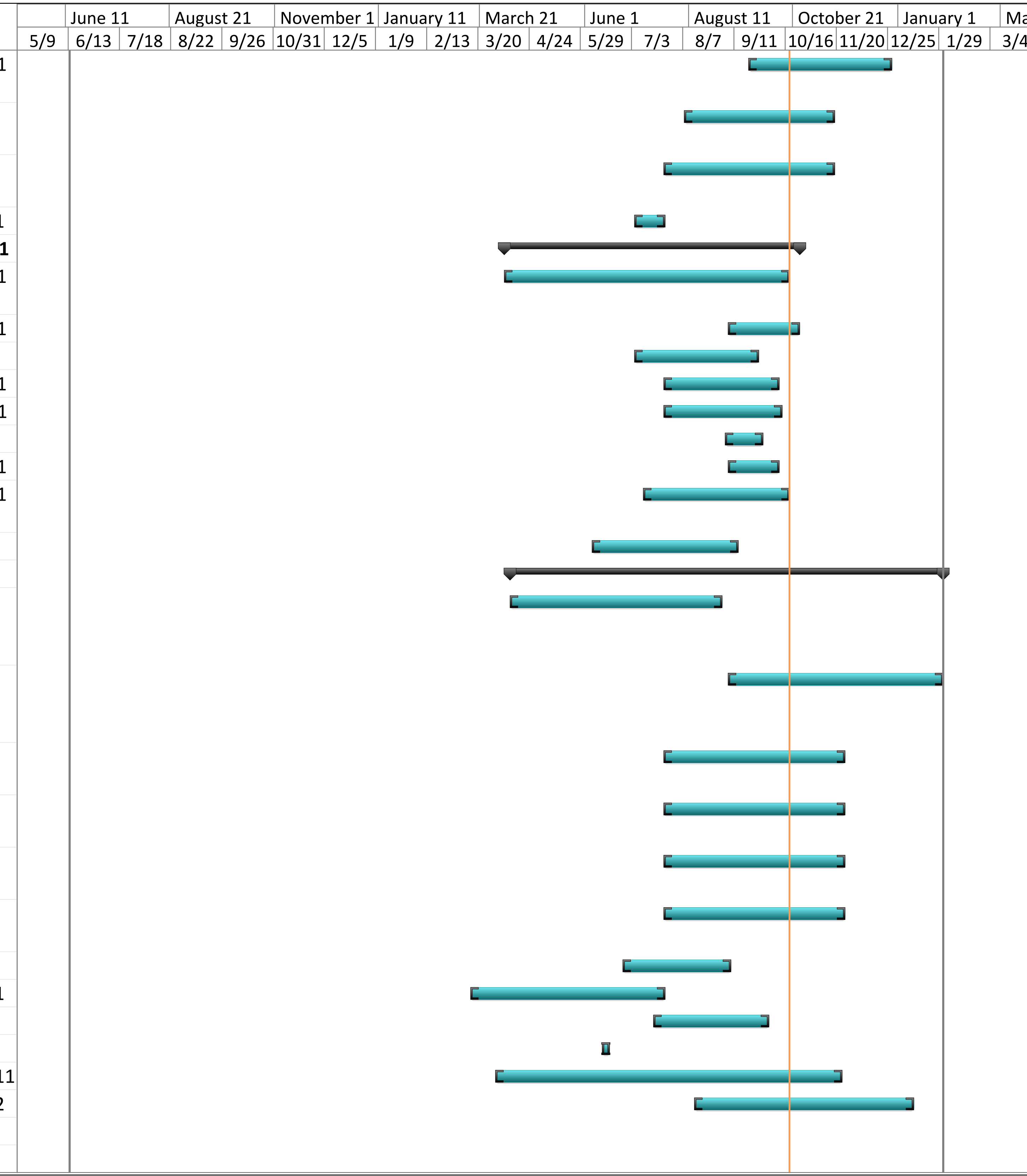
ID	Task Name	Duration	Start	Finish
159	**Rail Receiving**	**28 days**	**Thu 7/28/11**	**Mon 9/5/11**
160	Steel Framing	26 days	Thu 7/28/11	Thu 9/1/11
161	Joists & metal Decking	28 days	Thu 7/28/11	Mon 9/5/11
162	IMP Girts & Channels	3 days	Thu 9/1/11	Mon 9/5/11
163	Basement Mezzanine Steel & Deck (18 - 19 / A.3 - C)	39 days	Mon 4/25/11	Thu 6/16/11
164	**Install Mezzanine Steel & Metal Deck**	**69 days**	**Fri 4/22/11**	**Wed 7/27/11**
165	(A - H.9)	17 days	Wed 5/18/11	Thu 6/9/11
166	(C - E / 20)	10 days	Thu 7/14/11	Wed 7/27/11
167	(H.9 - U)	29 days	Fri 4/22/11	Wed 6/1/11
168	Utility Building Steel Erection, deck & detailing	16 days	Fri 3/25/11	Fri 4/15/11
169	Elevated Walkway Steel, Deck & Rails	10 days	Tue 6/21/11	Sun 7/3/11
170	Miscllaneous Metals & Stairs	113 days	Wed 4/6/11	Fri 9/9/11
171	Insulated Metal panels	110 days	Mon 4/11/11	Fri 9/9/11
172	Vertical Transportation	84 days	Wed 6/1/11	Mon 9/26/11
173	**Fire protection**	**98 days**	**Mon 5/16/11**	**Wed 9/28/11**
174	Basement: dry Sprinkler hangers, Mains & branches, Drops & heads, Valve assembly	87 days	Mon 5/16/11	Tue 9/13/11
175	Under Mezz: dry Sprinkler hangers, Mains & branches, Drops & heads, Valve assembly	13 days	Fri 7/1/11	Tue 7/19/11
176	Silo: dry Sprinkler hangers, Mains & branches, Drops & heads, Valve assembly	20 days	Mon 7/18/11	Fri 8/12/11
177	Rail Shed: dry Sprinkler hangers, Mains & branches, Drops & heads, Valve assembly	12 days	Tue 9/13/11	Wed 9/28/11
178	First Floor: dry Sprinkler hangers, Mains & branches, Drops & heads, Valve assembly	40 days	Mon 8/1/11	Fri 9/23/11
179	**Plumbing**	**172 days**	**Mon 5/2/11**	**Tue 12/27/11**
180	Silo Area: Install Roof Drains &Storm Piping; Plumbing Branch Runouts; Branch Insulation; Fixtures and Trim	30 days	Mon 8/22/11	Fri 9/30/11
181	Mould Wash Area: Install Roof Drains &Storm Piping; Plumbing Branch Runouts; Branch Insulation; Fixtures and Trim	30 days	Mon 6/20/11	Fri 7/29/11
182	Rail Receiving Area: Install Roof Drains &Storm Piping; Plumbing Branch Runouts; Branch Insulation; Fixtures and Trim	30 days	Tue 9/27/11	Mon 11/7/11
183	Lecithin Area: Install Roof Drains &Storm Piping; Plumbing Branch Runouts; Branch Insulation; Fixtures and Trim	14 days	Wed 8/24/11	Mon 9/12/11
184	Basement Area: Install Roof Drains &Storm Piping; Plumbing Branch Runouts; Branch Insulation; Fixtures and Trim	20 days	Wed 9/7/11	Tue 10/4/11
185	Level 1 Floor Drainage	25 days	Mon 5/2/11	Fri 6/3/11
186	(A - E) Area: Install Roof Drains &Storm Piping; Plumbing Branch Runouts; Branch Insulation; Fixtures and Trim; In-wall plumbing	50 days	Wed 10/5/11	Tue 12/13/11
187	Syrup Area: Install Roof Drains &Storm Piping; Plumbing Branch Runouts; Branch Insulation; Fixtures and Trim; In-wall plumbing	50 days	Wed 10/19/11	Tue 12/27/11



Project: Schedule 2
Date: Wed 10/19/11

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

ID		Task Name	Duration	Start	Finish
188		(E - H.9) Area: Install Roof Drains &Storm Piping; Plumbing Branch Runouts; Branch Insulation; Fixtures and Trim; In-wall plumbing	70 days	Wed 9/21/11	Tue 12/27/11
189		(H.9 - P) Area: Install Roof Drains &Storm Piping; Plumbing Branch Runouts; Branch Insulation; Fixtures and Trim; In-wall plumbing	75 days	Mon 8/8/11	Fri 11/18/11
190		(P - U) Area: Install Roof Drains &Storm Piping; Plumbing Branch Runouts; Branch Insulation; Fixtures and Trim; In-wall plumbing	85 days	Mon 7/25/11	Fri 11/18/11
191		Install & Connect DW Booster Pumps, CA Dryer & Accessories	15 days	Tue 7/5/11	Mon 7/25/11
192		**HVAC"**	**144 days**	**Thu 4/7/11**	**Tue 10/25/11**
193		Basement: Hangers & Pipe Rack Support, Install utilities on Pipe Racks; Piping & DuctWork; Unit cooler Pipe Connections; branches	139 days	Thu 4/7/11	Tue 10/18/11
194		(A - E): HVAC Pipe Mains & Branches + Insulation	35 days	Wed 9/7/11	Tue 10/25/11
195		UTB: HVAC Pipe Mains & Branches + Insulation	61 days	Tue 7/5/11	Tue 9/27/11
196		(E - H.9): HVAC Pipe Mains & Branches + Insulation	57 days	Mon 7/25/11	Tue 10/11/11
197		(H.9 - P): HVAC Pipe Mains & Branches + Insulation	59 days	Mon 7/25/11	Thu 10/13/11
198		Install Unit heaters, In-Wall exhaust Fans,	20 days	Mon 9/5/11	Fri 9/30/11
199		Piping & DuctWork Connections - RTU's	25 days	Wed 9/7/11	Tue 10/11/11
200		Install & Connect heat Exchangers, Cooling Tower, Blower Coil unit, Fan Coil Units, Exhaust Fans	72 days	Mon 7/11/11	Tue 10/18/11
201		Ductwork Mains & Branches	72 days	Mon 6/6/11	Tue 9/13/11
202		**Electrical Systems"**	**212 days**	**Mon 4/11/11**	**Tue 1/31/12**
203		Basement: Electrical Hangers & Supports; Lighting & Power; Trim-out Electrical Devices; Panel & Transformer Terms; Unit Cooler Power Connections	105 days	Mon 4/11/11	Fri 9/2/11
204		UTB: Electrical Hangers & Supports; Lighting & Power; Trim-out Electrical Devices; Panel & Transformer Terms; Unit Cooler Power Connections	105 days	Wed 9/7/11	Tue 1/31/12
205		(A - E): Electrical Hangers & Supports; Lighting & Power Conduit + Wiring; Panel & Transformer Terms; Light fixtures	90 days	Mon 7/25/11	Fri 11/25/11
206		(E - H.9):Electrical Hangers & Supports; Lighting & Power Conduit + Wiring; Panel & Transformer Terms; Light fixtures	90 days	Mon 7/25/11	Fri 11/25/11
207		(H.9 - P): Electrical Hangers & Supports; Lighting & Power Conduit + Wiring; Panel & Transformer Terms; Light fixtures	90 days	Mon 7/25/11	Fri 11/25/11
208		(P - U):Electrical Hangers & Supports; Lighting & Power Conduit + Wiring; Panel & Transformer Terms; Light fixtures	90 days	Mon 7/25/11	Fri 11/25/11
209		Parking Lots: Site Light fixtures, U.Power / Light	54 days	Mon 6/27/11	Thu 9/8/11
210		Masonry	95 days	Tue 3/15/11	Mon 7/25/11
211		Landscaping	57 days	Mon 7/18/11	Tue 10/4/11
212		Fuala Equipment Installation	5 days	Mon 6/13/11	Fri 6/17/11
213		Utility Shutdowns & Tie-ins	169 days	Fri 4/1/11	Wed 11/23/11
214		Equipment/ System Start-up & Commissioning	108 days	Mon 8/15/11	Wed 1/11/12
215					
216					



Project: Schedule 2
Date: Wed 10/19/11

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

Appendix G

Assembly Detail Report

Assembly Detail Report

Cost Estimate Report CostWorks RSMeans

Year 2011 Quarter 3

Date: 22-Sep-11

West Expansion Electrical Assembly Estimate

Prepared By:
Jaafar Al Aidaroos
psu

Assembly Number			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
D Services							
D50101200360			Service installation, includes breakers, metering, 20' conduit & wire, 3 phase, 4 wire, 120/208 V, 600 A	2.50	Ea.	$12,427.18	$31,067.95
D50102300360			Feeder installation 600 V, including RGS conduit and XHHW wire, 600 A	3,326.00	L.F.	$171.79	$571,373.54
D50102400320			Switchgear installation, incl switchboard, panels & circuit breaker, 1200 A	4.80	Ea.	$31,675.60	$152,042.88
D50201100320			Receptacles incl plate, box, conduit, wire, 4 per 1000 SF, .5 W per SF, with transformer	324,403.00	S.F.	$2.01	$652,050.03
D50201300320			Wall switches, 2.5 per 1000 SF	324,403.00	S.F.	$0.50	$162,201.50
D50201400240			Central air conditioning power, 3 watts	324,403.00	S.F.	$0.38	$123,273.14
D50202100540			Fluorescent fixtures recess mounted in ceiling, 2.4 watt per SF, 60 FC, 15 fixtures @ 32 watt per 1000 SF	324,403.00	S.F.	$7.26	$2,355,165.78
D50303100280			Telephone systems, underfloor duct, 7' on center, low density	324,403.00	S.F.	$10.42	$3,380,279.26
D50309100454			Communication and alarm systems, fire detection, addressable, 50 detectors, includes outlets, boxes, conduit and wire	1.00	Ea.	$36,141.90	$36,141.90
D50309100600			Communication and alarm systems, includes outlets, boxes, conduit and wire, intercom systems, 50 stations	1.00	Ea.	$57,832.70	$57,832.70
D Services Subtotal							**$7,521,428.68**

Assembly Detail Report

Cost Estimate Report CostWorks® RSMeans

Year 2011 Quarter 3

West Expansion Mechanical Assembly Estimate

Date: 22-Sep-11

Prepared By:
Jaafar Alaidaroos
PSU

Assembly Number			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
D Services							
D30105202080			Commercial building heating system, fin tube radiation, forced hot water, 1mil SF, 10 mil CF, total 5 floors	324,403.00	S.F.	$2.10	$681,246.30
D30201041320			Large heating systems, electric boilers, hydronic, 18,600 SF, 296 KW, 1,010 MBH, 3 floors	324,403.00	S.F.	$9.50	$3,081,828.50
D30301153200			Packaged chiller, water cooled, with fan coil unit, factories, 60,000 SF, 200.00 ton	324,403.00	S.F.	$13.20	$4,282,119.60
D30501503120			Rooftop, single zone, air conditioner, factories, 10,000 SF, 33.33 ton	324,403.00	S.F.	$8.57	$2,780,133.71
D Services Subtotal							**$10,825,328.11**

Assembly Detail Report

Abu Dhabi,

Year 2011 Quarter 3

Date: 22-Sep-11

West Expansion Plumbing Assembly Estimate

Prepared By:
Jaafar Al Aidaroos
psu

Assembly Number			Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
D Services							
D20101101960			Water closet, vitreous china, tank type, 1 piece low profile	43.00	Ea.	$1,747.32	$75,134.76
D20102102000			Urinal, vitreous china, wall hung	16.00	Ea.	$1,355.23	$21,683.68
D20103102040			Lavatory w/trim, wall hung, PE on CI, 18" x 15"	43.00	Ea.	$1,641.51	$70,584.93
D20104404300			Service sink w/trim, PE on CI,wall hung w/rim guard, 22" x 18"	3.00	Ea.	$3,449.43	$10,348.29
D20107101960			Shower, built-in head, arm, bypass, stops and handles	2.00	Ea.	$404.96	$809.92
D20108201880			Water cooler, electric, wall hung, dual height, 14.3 GPH	6.00	Ea.	$2,198.01	$13,188.06
D20202401820			Electric water heater, commercial, 100< F rise, 50 gallon tank, 9 KW 37 GPH	6.00	Ea.	$5,518.18	$33,109.08
D20202401940			Electric water heater, commercial, 100< F rise, 120 gal, 36 KW 147 GPH	1.00	Ea.	$10,818.68	$10,818.68
D20402102200			Roof drain, DWV PVC, 6" diam, 10' high	51.00	Ea.	$2,275.58	$116,054.58
D20402102240			Roof drain, DWV PVC, 6" diam, for each additional foot add	23.00	Ea.	$46.84	$1,077.32
D Services Subtotal							**$352,809.30**

Appendix H

General Conditions Estimate

General Conditions Estimate	
Non Personnel Expenses	$596,305.00
Primary Personnel	$3,542,000.00
TOTAL	$4,138,305.00

GC non Personnel Actual vs. Estimated	
Actual Cost	Estimated Cost
$990,000.00	$596,305.00

Primary Personnel				
Activity	Quantity	Units	Unit Rate	Total Cost
Project Executive	3080	MHR	140	$431,200.00
Sr. Project Manager	3080	MHR	125	$385,000.00
Superintendent	3080	MHR	100	$308,000.00
Superintendent	3080	MHR	100	$308,000.00
Superintendent	3080	MHR	100	$308,000.00
Project Manager	3080	MHR	90	$277,200.00
Project Manager	3080	MHR	90	$277,200.00
MEP Coordinator	3080	MHR	90	$277,200.00
Assistant Project Manager	3080	MHR	55	$169,400.00
Cost Engineer	3080	MHR	90	$277,200.00
Project Scheduler	3080	MHR	100	$308,000.00
Project Accountant	3080	MHR	70	$215,600.00
TOTAL				$3,542,000.00

Non Personnel Expenses				
Activity	Quantity	Units	Unit Rate	Total Cost
Project Signs	17	Mo	1200	$20,400.00
Tool Rentals	17	Mo	500	$8,500.00
Housing Expenses	17	Mo	6650	$113,050.00
Travel Expenses	17	Mo	6000	$102,000.00
Meeting Expenses	17	Mo	525	$8,925.00
Office Trailers - Set Up	1	LS	12500	$12,500.00
Office Trailers - Rental	17	Mo	2400	$40,800.00
Electric - Consumption	17	Mo	600	$10,200.00
Water & Sanitary Consumption	17	Mo	250	$4,250.00
Alarm - Set-up	1	LS	1500	$1,500.00
Alarm - Monthly	17	Mo	200	$3,400.00
Telephones - Monthly	17	Mo	1125	$19,125.00
Mobile/Cellular	17	Mo	100	$1,700.00
Stationary & Supplies	17	Mo	1150	$19,550.00
Copier	1	LS	52500	$52,500.00
Fax Machine	1	LS	2500	$2,500.00
Business Machine Maintenance	17	Mo	250	$4,250.00
Computer Equipment	17	Mo	3110	$52,870.00
Progress Photos	17	Mo	625	$10,625.00
BIM services	1	Allow	40000	$40,000.00
Personal Protective Equipment	1	LS	11250	$11,250.00
Porta - Johns - On Grade	17	Mo	1450	$24,650.00
Office Trailer Removal	1	LS	23260	$23,260.00
Temp. Storage Trailers	17	Mo	500	$8,500.00
TOTAL				$596,305.00

Appendix 7

Energy Model Comparison

Autodesk

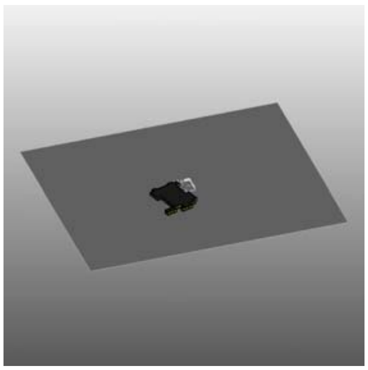
Energy Analysis Compare Report

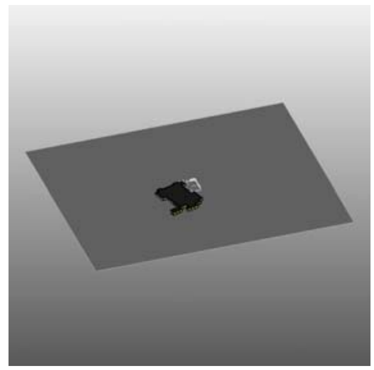
Report created at 2012-04-23 09:33:33 PM

Project1(Recovery).0002
Arch 1, 10 glazing, simple, no skylights
Analyzed at 4/23/2012 7:20:41 PM
Version 2012.0.23.9936(DOE-2.2-44e4)

Project1(Recovery).0002
Arch 1, 10 glazing, simple, shading, no skylights
Analyzed at 4/23/2012 7:23:10 PM
Version 2012.0.23.9936(DOE-2.2-44e4)

Mass





Building Performance Factors

Location:	Hershey, PA, USA
Weather Station:	53158
Outdoor Temperature:	Max: 82°F/Min: -10°F
Floor Area:	277,954 sf
Exterior Wall Area:	166,657 sf
Average Lighting Power:	1.30 W / ft²
People:	646 people
Exterior Window Ratio:	0.10
Electrical Cost:	$0.09 / kWh
Fuel Cost:	$1.03 / Therm

Location:	Hershey, PA, USA
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Average Lighting Power:	1.30 W / ft²
People:	646 people
Exterior Window Ratio:	0.10
Electrical Cost:	$0.09 / kWh
Fuel Cost:	$1.03 / Therm

Energy Use Intensity

Electricity EUI:	15 kWh / sf / yr
Fuel EUI:	20 kBtu / sf / yr
Total EUI:	72 kBtu / sf / yr

Electricity EUI:	15 kWh / sf / yr
Fuel EUI:	20 kBtu / sf / yr
Total EUI:	72 kBtu / sf / yr

Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	127,225,680 kWh
Life Cycle Fuel Use:	1,682,410 Therms
Life Cycle Energy Cost:	$6,201,082

*30-year life and 6.1% discount rate for costs

Life Cycle Electricity Use:	126,478,350 kWh
Life Cycle Fuel Use:	1,682,737 Therms
Life Cycle Energy Cost:	$6,169,409

*30-year life and 6.1% discount rate for costs

Renewable Energy Potential

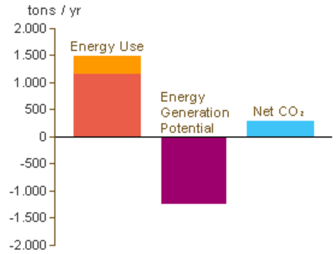
Roof Mounted PV System (Low efficiency):	1,460,330 kWh / yr
Roof Mounted PV System (Medium efficiency):	2,920,659 kWh / yr
Roof Mounted PV System (High efficiency):	4,380,989 kWh / yr
Single 15' Wind Turbine Potential:	2,969 kWh / yr

*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems

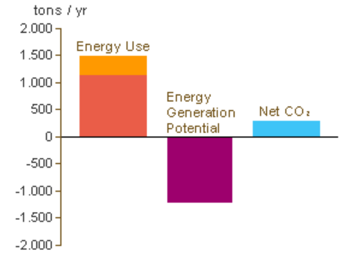
Roof Mounted PV System (Low efficiency):	1,439,389 kWh / yr
Roof Mounted PV System (Medium efficiency):	2,878,778 kWh / yr
Roof Mounted PV System (High efficiency):	4,318,167 kWh / yr
Single 15' Wind Turbine Potential:	2,969 kWh / yr

*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high effi systems

Emissions

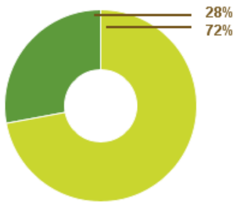


	(tons / yr)
Electricity Consumption	1,172
Fuel Consumption	325
Roof PV Potential (High Efficiency)	-1,211
Single 15' Wind Turbine Potential	0
Net CO_2	286

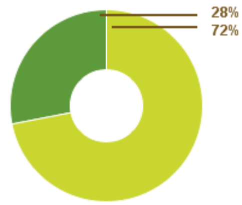


	(tons / yr)
Electricity Consumption	1,165
Fuel Consumption	325
Roof PV Potential (High Efficiency)	-1,193
Single 15' Wind Turbine Potential	0
Net CO_2	297

Annual Energy Use/Cost

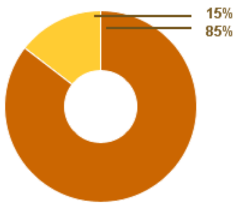


Electricity	72%	$397,792	4,240,856	kWh
Fuel	28%	$57,500	56,080	Therms
		$455,292		

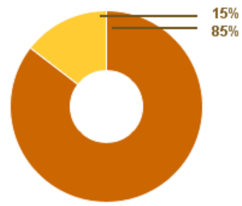


Electricity	72%	$395,456	4,215,945	kWh
Fuel	28%	$57,511	56,091	Therms
		$452,967		

Energy Use: Fuel

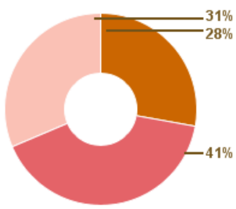


			(Therms)
HVAC	85%	$49,136	47,923
Domestic Hot Water	15%	$8,363	8,157
		$57,499	56,080

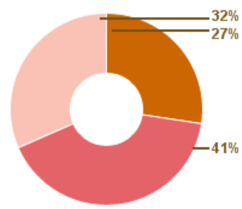


			(Therms)
HVAC	85%	$49,147	47,934
Domestic Hot Water	15%	$8,363	8,157
		$57,510	56,091

Energy Use: Electricity

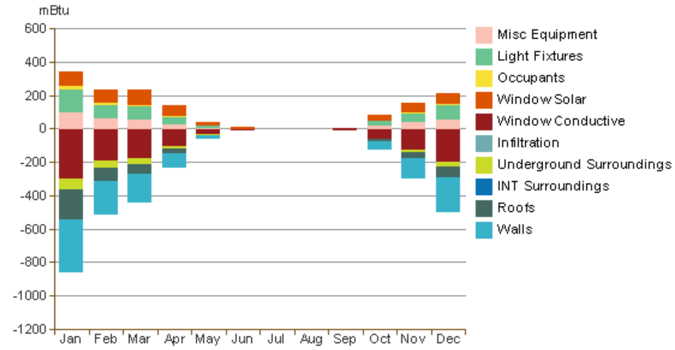


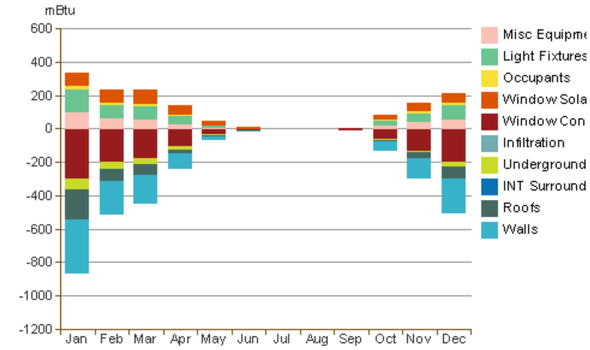
			(kWh)
HVAC	28%	$110,698	1,180,151
Lighting	41%	$162,263	1,729,883
Misc Equipment	31%	$124,831	1,330,824
		$397,792	4,240,858



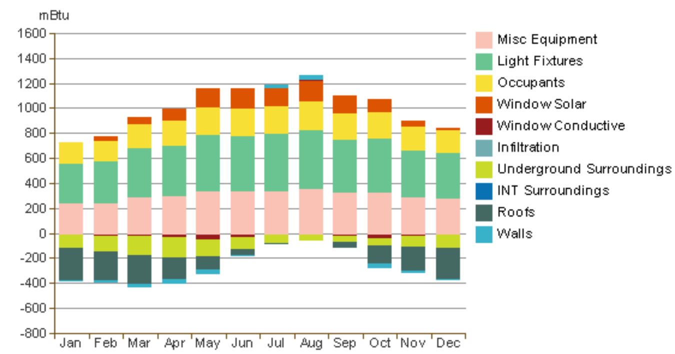
			(kWh)
HVAC	27%	$108,361	1,155,239
Lighting	41%	$162,263	1,729,883
Misc Equipment	32%	$124,831	1,330,824
		$395,455	4,215,946

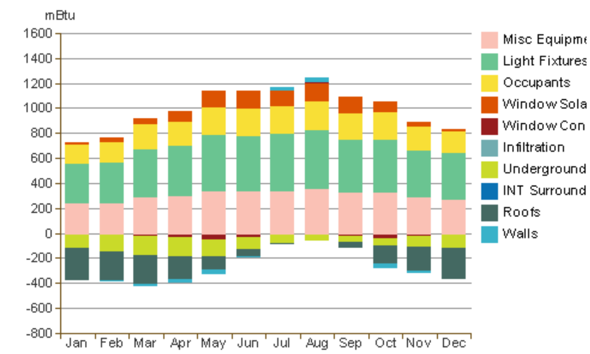
Monthly Heating Load



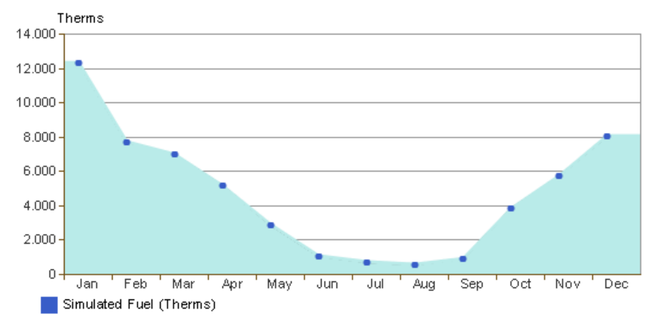


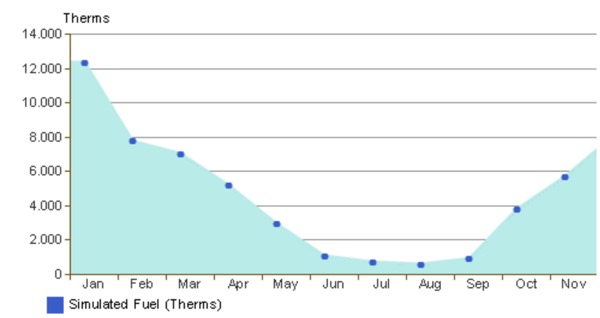
Monthly Cooling Load



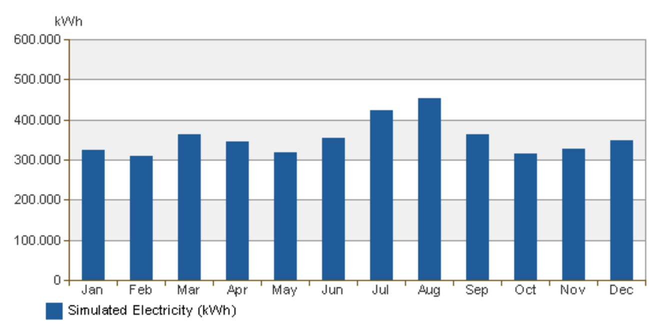


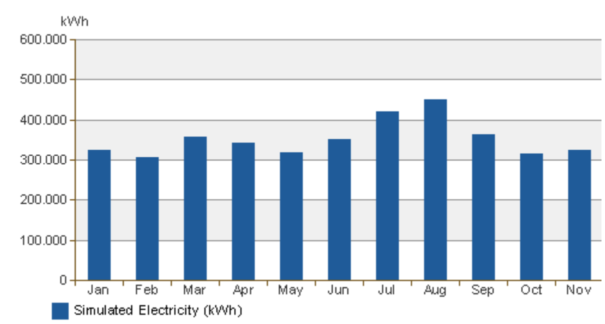
Monthly Fuel Consumption



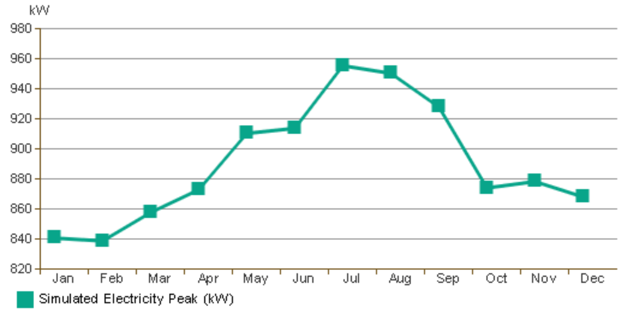


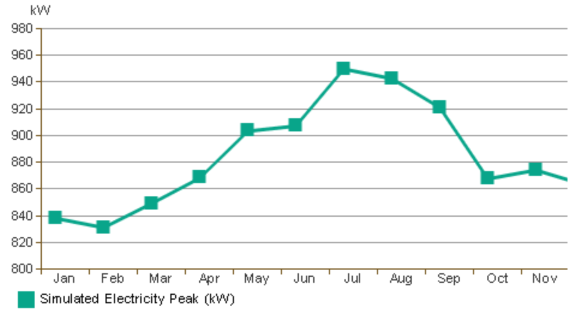
Monthly Electricity Consumption



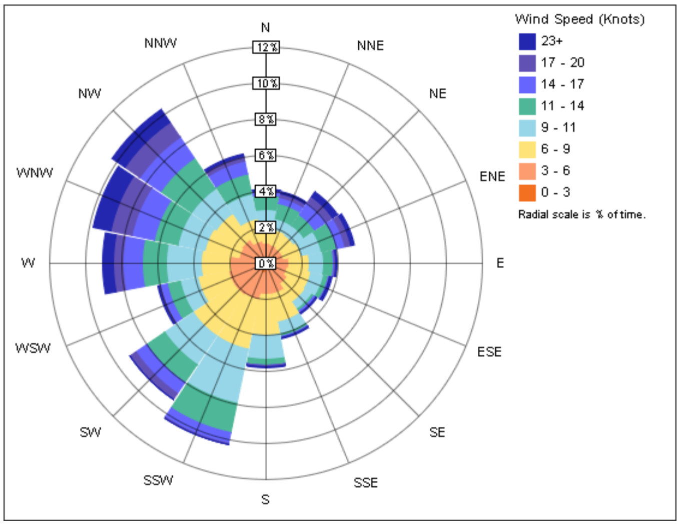


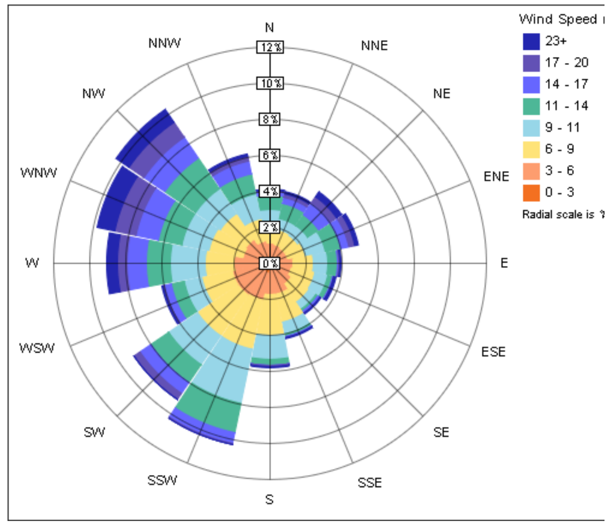
Monthly Peak Demand



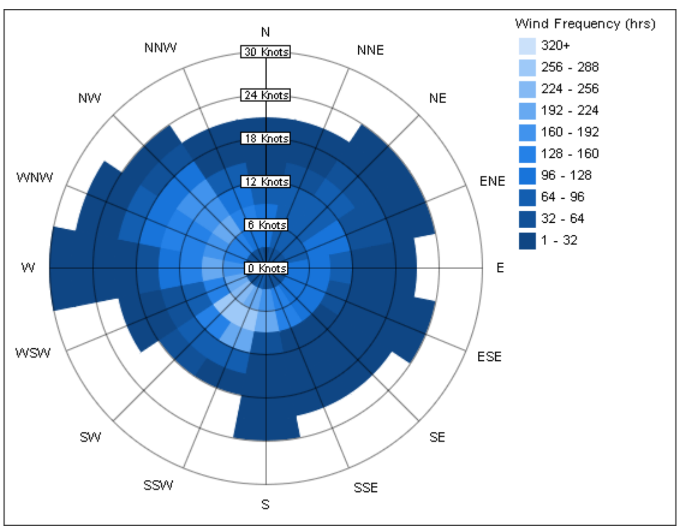


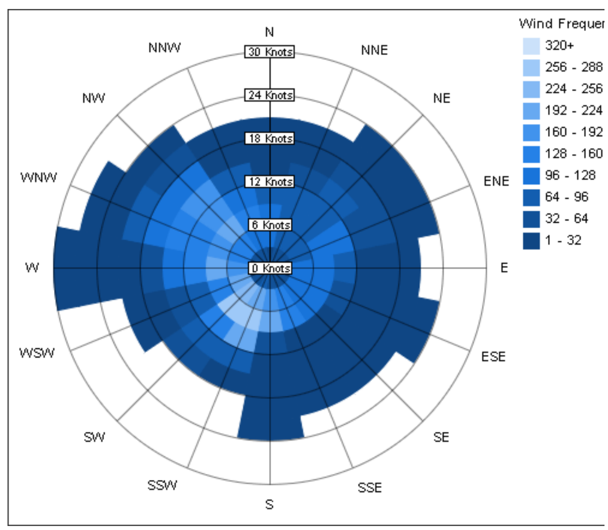
Annual Wind Rose (Speed Distribution)



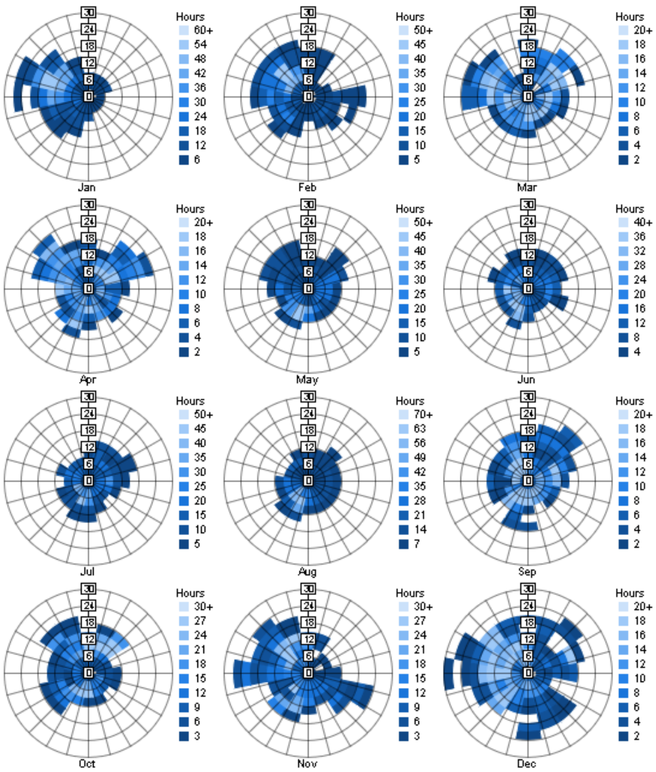


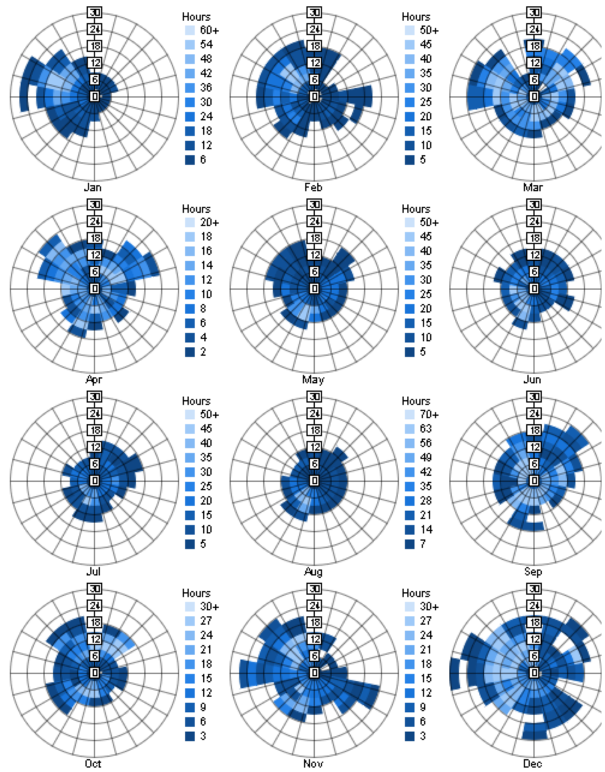
Annual Wind Rose (Frequency Distribution)



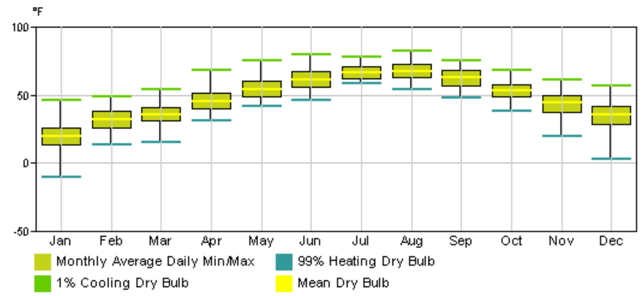


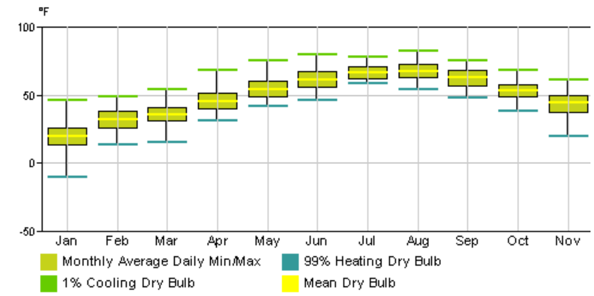
Monthly Wind Roses



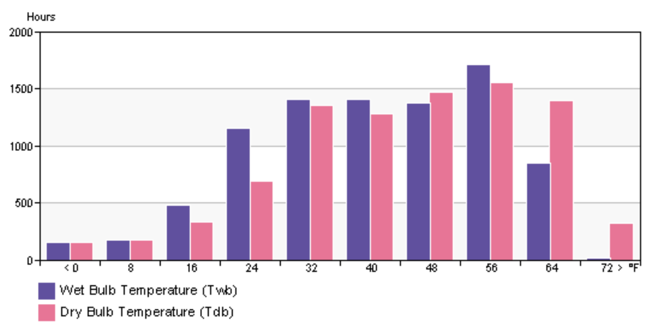


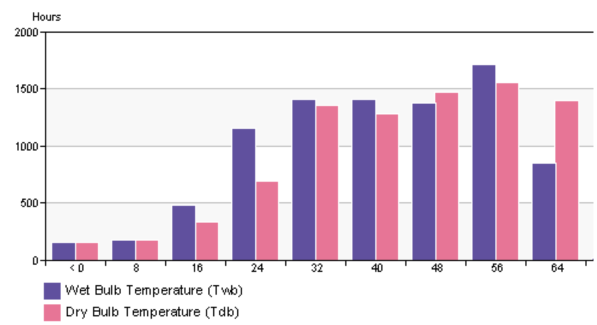
Monthly Design Data



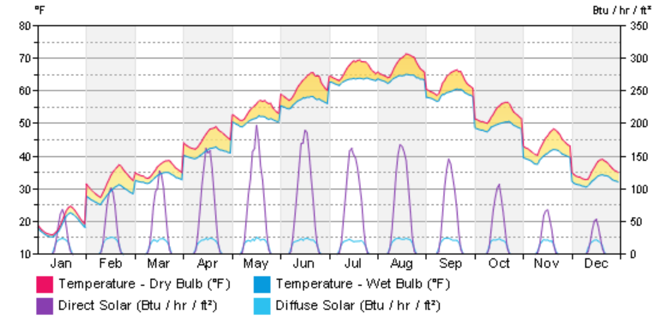


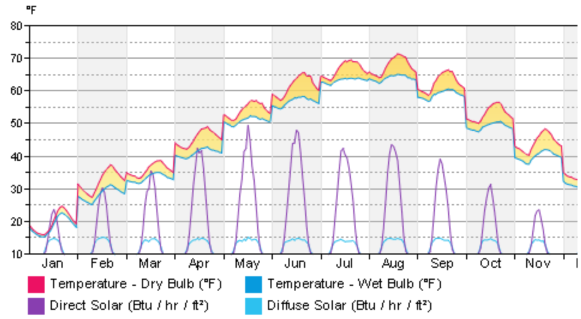
Annual Temperature Bins

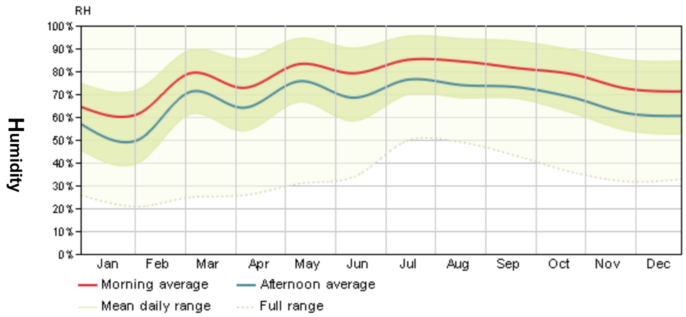


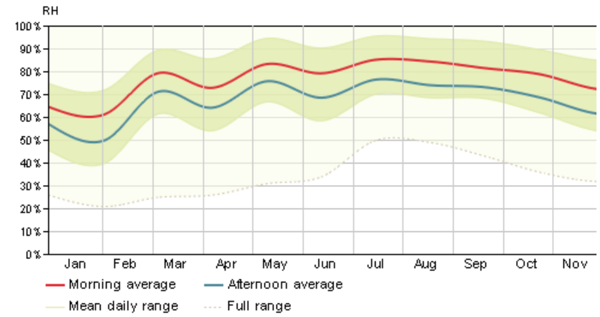


Diurnal Weather Averages









Revit Conceptual Energy Analysis Data

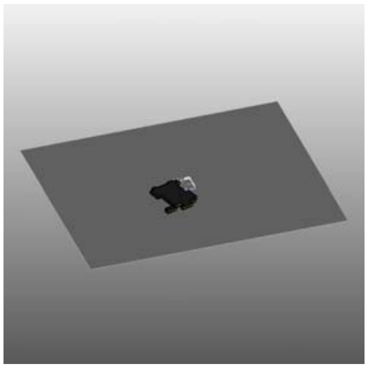
Autodesk®

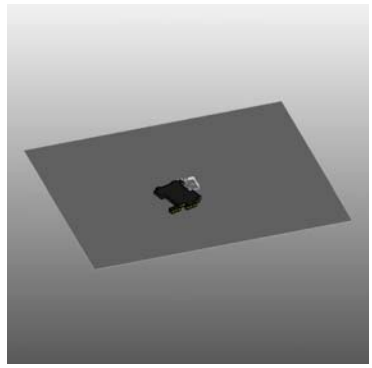
Energy Analysis Compare Report

Report created at 2012-04-23 09:34:28 PM

	Project1(Recovery).0002 **1. Arch 1, 20 glazing, simple, no skylights** Analyzed at 4/23/2012 7:18:02 PM Version 2012.0.23.9936(DOE-2.2-44e4)	**Project1(Recovery).0002** **Arch 1, 10 glazing, simple, no skylights** Analyzed at 4/23/2012 7:20:41 PM Version 2012.0.23.9936(DOE-2.2-44e4)

Mass





Building Performance Factors

Location:	Hershey, PA, USA		Location:	Hershey, PA, USA
Weather Station:	53158		Weather Station:	53158
Outdoor Temperature:	Max: 82°F/Min: -10°F		Outdoor Temperature:	Max: 82°F/Min: -10°F
Floor Area:	277,954 sf		Floor Area:	277,954 sf
Exterior Wall Area:	166,657 sf		Exterior Wall Area:	166,657 sf
Average Lighting Power:	1.30 W / ft²		Average Lighting Power:	1.30 W / ft²
People:	646 people		People:	646 people
Exterior Window Ratio:	0.20		Exterior Window Ratio:	0.10
Electrical Cost:	$0.09 / kWh		Electrical Cost:	$0.09 / kWh
Fuel Cost:	$1.03 / Therm		Fuel Cost:	$1.03 / Therm

Energy Use Intensity

Electricity EUI:	16 kWh / sf / yr		Electricity EUI:	15 kWh / sf / yr
Fuel EUI:	26 kBtu / sf / yr		Fuel EUI:	20 kBtu / sf / yr
Total EUI:	80 kBtu / sf / yr		Total EUI:	72 kBtu / sf / yr

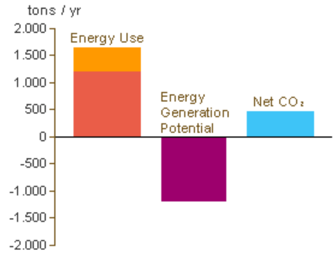
Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	133,478,310 kWh		Life Cycle Electricity Use:	127,225,680 kWh
Life Cycle Fuel Use:	2,140,019 Therms		Life Cycle Fuel Use:	1,682,410 Therms
Life Cycle Energy Cost:	$6,680,366		Life Cycle Energy Cost:	$6,201,082
*30-year life and 6.1% discount rate for costs			*30-year life and 6.1% discount rate for costs	

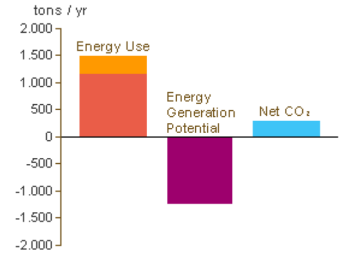
Renewable Energy Potential

Roof Mounted PV System (Low efficiency):	1,427,252 kWh / yr		Roof Mounted PV System (Low efficiency):	1,460,330 kWh / yr
Roof Mounted PV System (Medium efficiency):	2,854,503 kWh / yr		Roof Mounted PV System (Medium efficiency):	2,920,659 kWh / yr
Roof Mounted PV System (High efficiency):	4,281,755 kWh / yr		Roof Mounted PV System (High efficiency):	4,380,989 kWh / yr
Single 15' Wind Turbine Potential:	2,969 kWh / yr		Single 15' Wind Turbine Potential:	2,969 kWh / yr
*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems			*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high effi systems	

Emissions

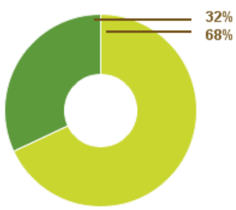


	(tons / yr)
Electricity Consumption	1,230
Fuel Consumption	413
Roof PV Potential (High Efficiency)	-1,183
Single 15' Wind Turbine Potential	0
Net CO_2	460

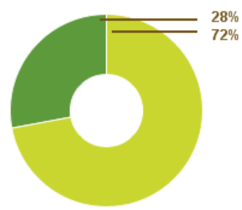


	(tons / yr)
Electricity Consumption	1,172
Fuel Consumption	325
Roof PV Potential (High Efficiency)	-1,211
Single 15' Wind Turbine Potential	0
Net CO_2	286

Annual Energy Use/Cost

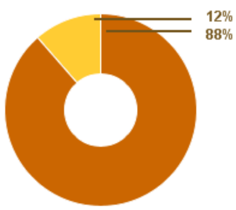


Electricity	68%	$417,342	4,449,277	kWh
Fuel	32%	$73,140	71,333	Therms
		$490,482		

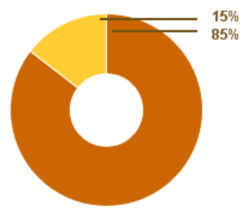


Electricity	72%	$397,792	4,240,856	kWh
Fuel	28%	$57,500	56,080	Therms
		$455,292		

Energy Use: Fuel

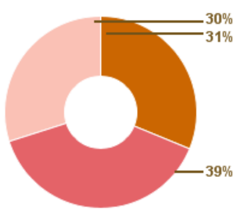


			(Therms)
HVAC	88%	$64,776	63,176
Domestic Hot Water	12%	$8,363	8,157
		$73,139	71,333

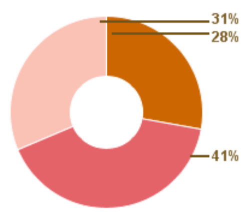


			(Therms)
HVAC	85%	$49,136	47,923
Domestic Hot Water	15%	$8,363	8,157
		$57,499	56,080

Energy Use: Electricity

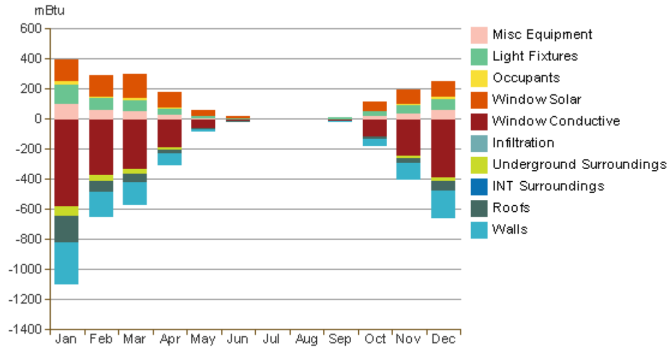


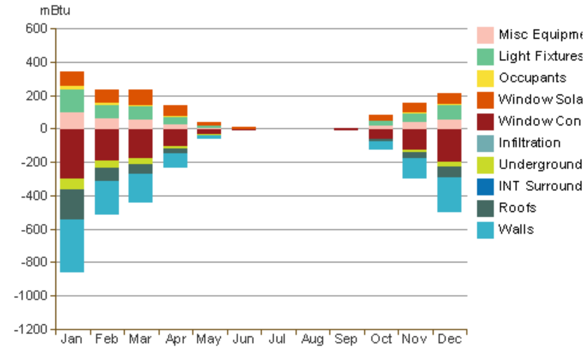
			(kWh)
HVAC	31%	$130,248	1,388,571
Lighting	39%	$162,263	1,729,883
Misc Equipment	30%	$124,831	1,330,824
		$417,342	4,449,278



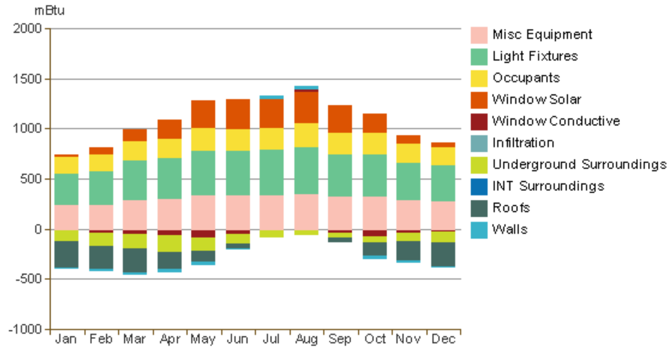
			(kWh)
HVAC	28%	$110,698	1,180,151
Lighting	41%	$162,263	1,729,883
Misc Equipment	31%	$124,831	1,330,824
		$397,792	4,240,858

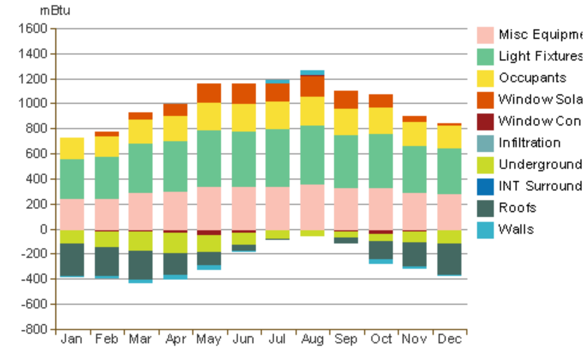
Monthly Heating Load



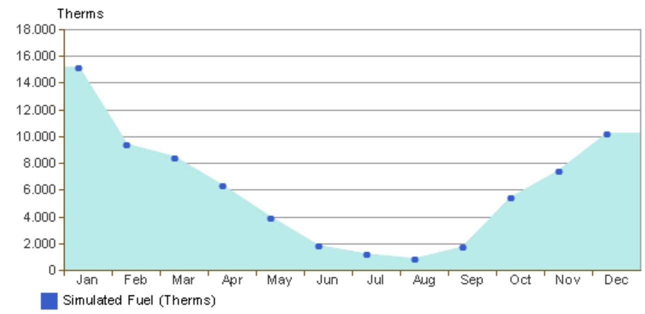


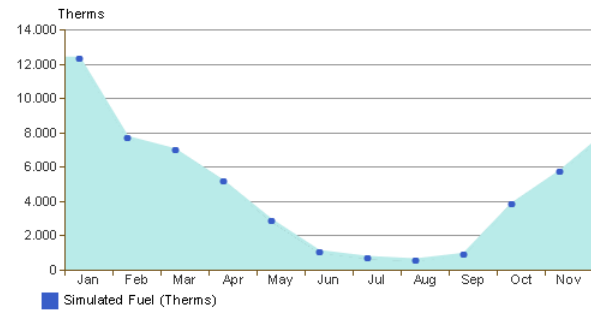
Monthly Cooling Load



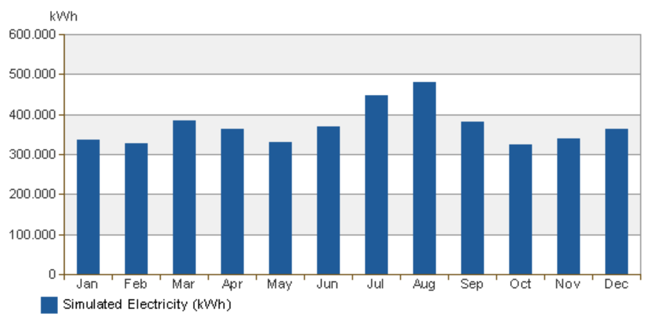


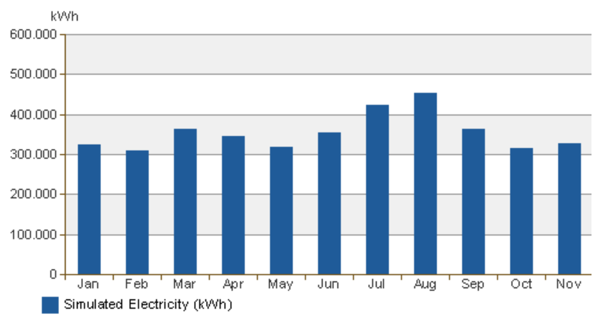
Monthly Fuel Consumption



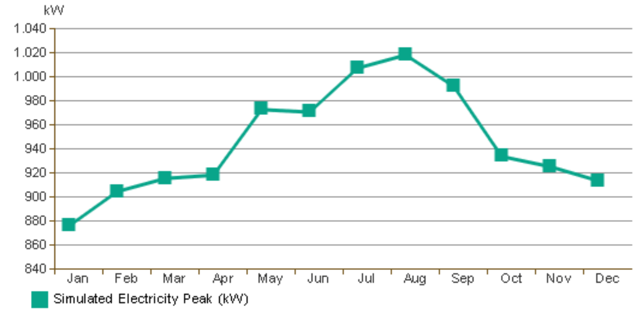


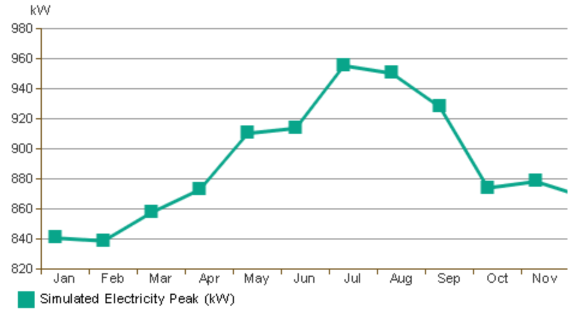
Monthly Electricity Consumption



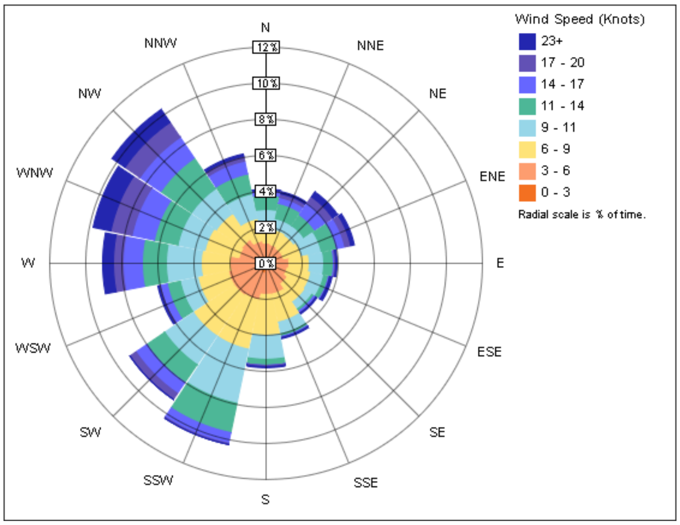


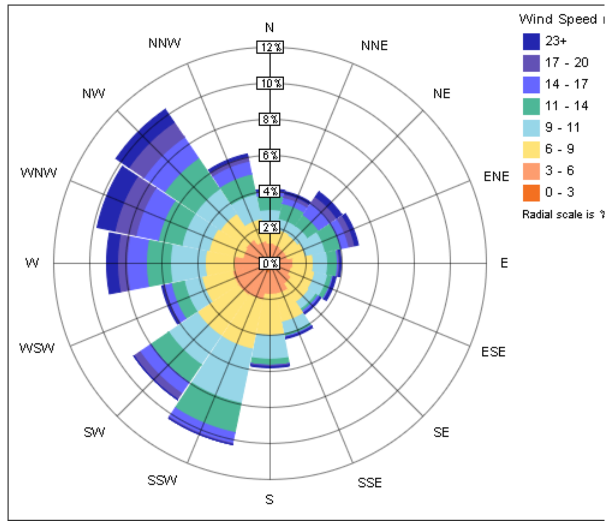
Monthly Peak Demand



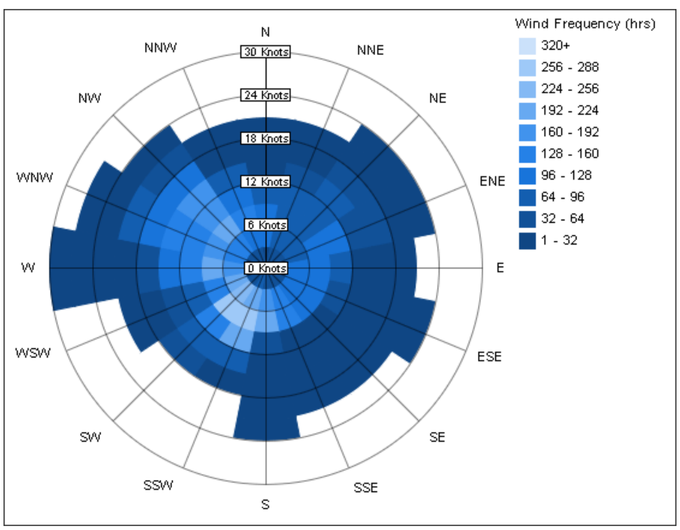


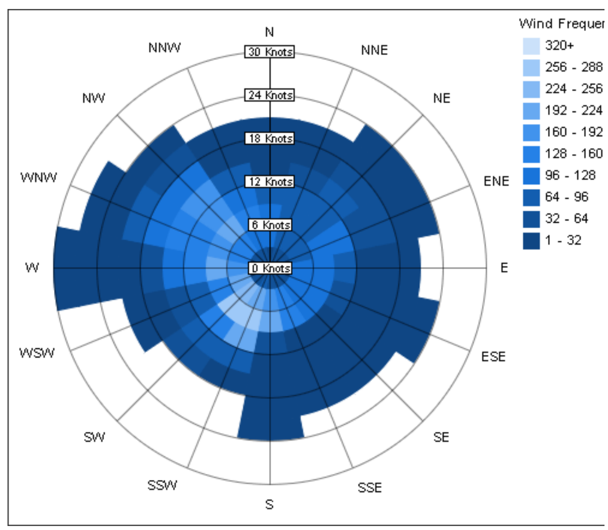
Annual Wind Rose (Speed Distribution)



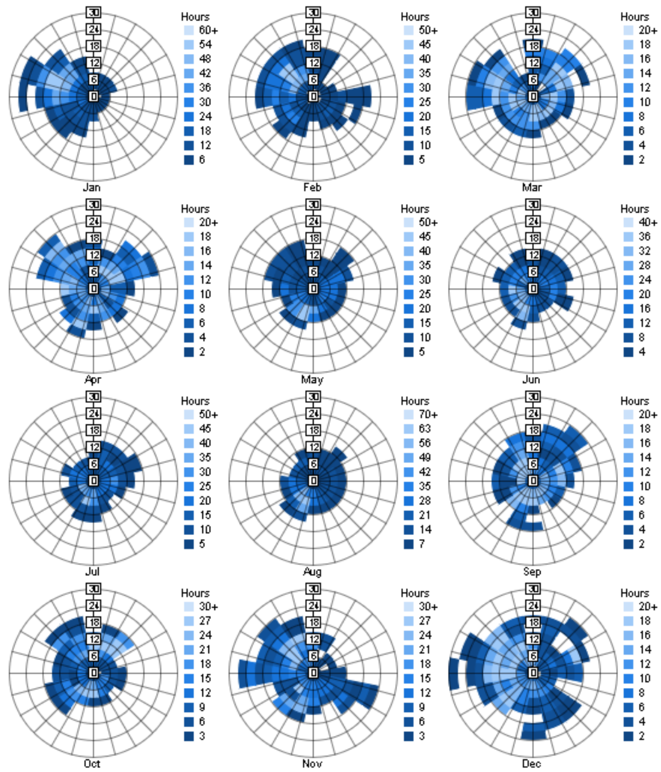


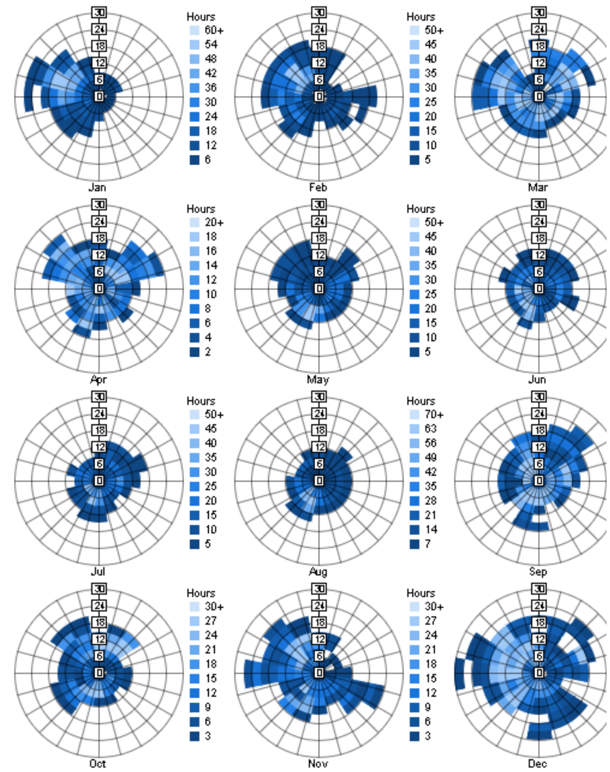
Annual Wind Rose (Frequency Distribution)



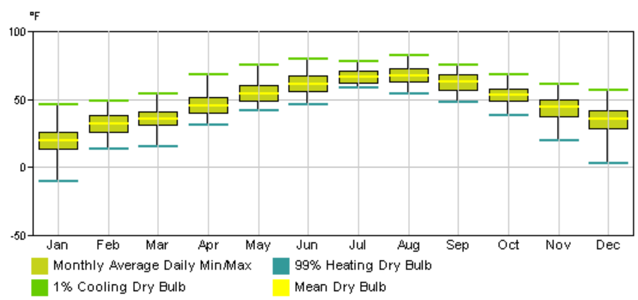


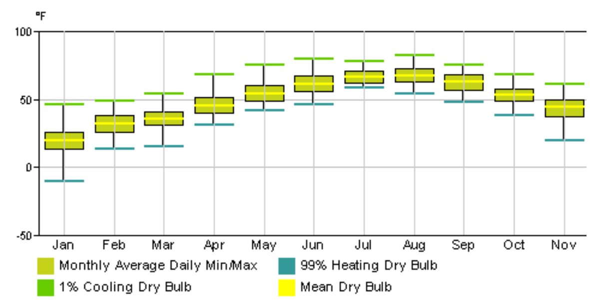
Monthly Wind Roses



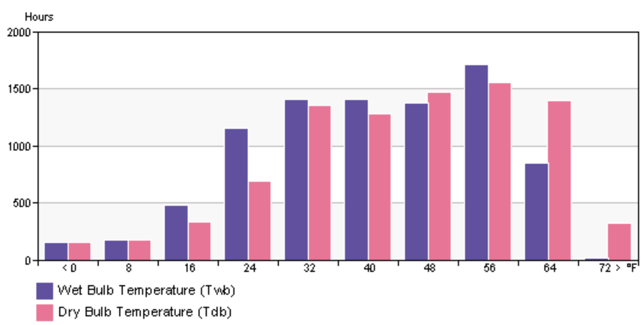


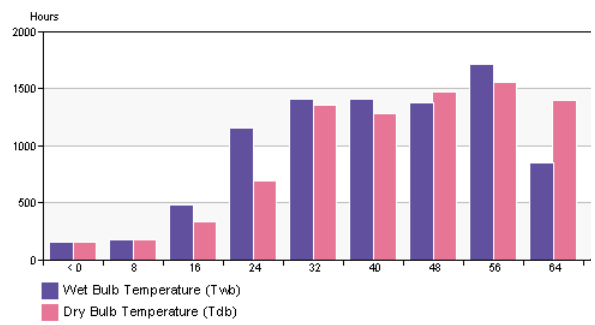
Monthly Design Data



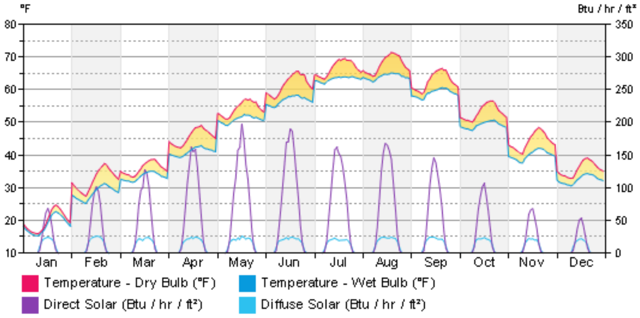


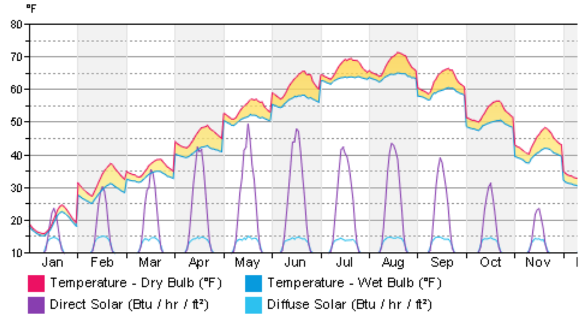
Annual Temperature Bins

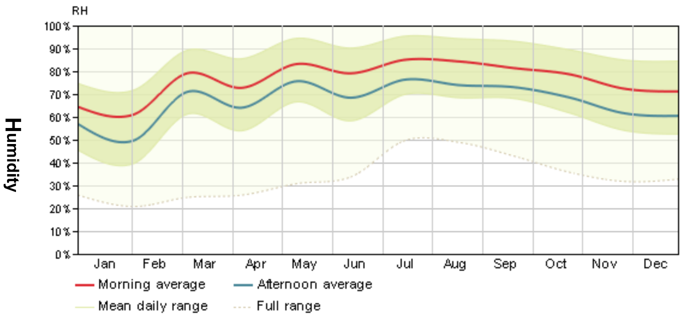


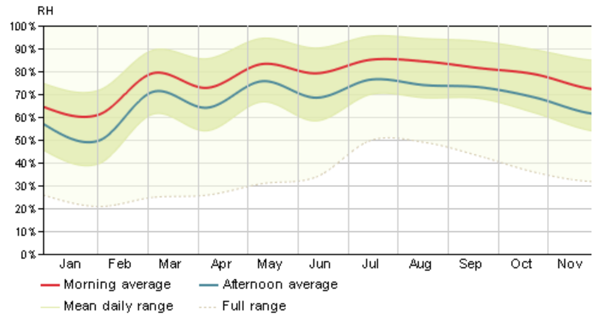


Diurnal Weather Averages









Revit Conceptual Energy Analysis Data

Appendix 8

Cumulative Lighting Load

	Energy (kWh)	Energy Value ($)	Fixed O&M	Variable O&M	Insurance	Property Assessed Value	Property Taxes
0	0	0	0	0	0	0	0
1	278,394	39,810.34	3,830.50	0	7,187.94	1,437,587.79	28,751.76
2	277,002	40,601.57	3,926.27	0	7,367.64	1,437,587.79	28,751.76
3	275,617	41,408.53	4,024.42	0	7,551.83	1,437,587.79	28,751.76
4	274,239	42,231.52	4,125.03	0	7,740.62	1,437,587.79	28,751.76
5	272,868	43,070.87	4,228.16	0	7,934.14	1,437,587.79	28,751.76
6	271,503	43,926.91	4,333.86	0	8,132.49	1,437,587.79	28,751.76
7	270,146	44,799.95	4,442.21	0	8,335.81	1,437,587.79	28,751.76
8	268,795	45,690.35	4,553.26	0	8,544.20	1,437,587.79	28,751.76
9	267,451	46,598.45	4,667.10	0	8,757.81	1,437,587.79	28,751.76
10	266,114	47,524.59	4,783.77	0	8,976.75	1,437,587.79	28,751.76
11	264,783	48,469.14	4,903.37	0	9,201.17	1,437,587.79	28,751.76
12	263,459	49,432.47	5,025.95	0	9,431.20	1,437,587.79	28,751.76
13	262,142	50,414.94	5,151.60	0	9,666.98	1,437,587.79	28,751.76
14	260,831	51,416.94	5,280.39	0	9,908.65	1,437,587.79	28,751.76
15	259,527	52,438.85	5,412.40	0	10,156.37	1,437,587.79	28,751.76
16	258,230	53,481.07	5,547.71	0	10,410.28	1,437,587.79	28,751.76
17	256,938	54,544.01	5,686.40	0	10,670.54	1,437,587.79	28,751.76
18	255,654	55,628.07	5,828.56	0	10,937.30	1,437,587.79	28,751.76
19	254,376	56,733.68	5,974.28	0	11,210.73	1,437,587.79	28,751.76
20	253,104	57,861.26	6,123.63	0	11,491	1,437,587.79	28,751.76
21	251,838	59,011.25	6,276.73	0	11,778.27	1,437,587.79	28,751.76
22	250,579	60,184.10	6,433.64	0	12,072.73	1,437,587.79	28,751.76
23	249,326	61,380.26	6,594.48	0	12,374.55	1,437,587.79	28,751.76
24	248,079	62,600.19	6,759.35	0	12,683.91	1,437,587.79	28,751.76
25	246,839	63,844.37	6,928.33	0	13,001.01	1,437,587.79	28,751.76
26	245,605	65,113.28	7,101.54	0	13,326.04	1,437,587.79	28,751.76
27	244,377	66,407.40	7,279.08	0	13,659.19	1,437,587.79	28,751.76
28	243,155	67,727.25	7,461.05	0	14,000.67	1,437,587.79	28,751.76
29	241,939	69,073.33	7,647.58	0	14,350.68	1,437,587.79	28,751.76
30	240,729	70,446.16	7,838.77	0	14,709.45	1,437,587.79	28,751.76
31	239,526	71,846.28	8,034.74	0	15,077.19	1,437,587.79	28,751.76
32	238,328	73,274.22	8,235.61	0	15,454.12	1,437,587.79	28,751.76
33	237,137	74,730.55	8,441.50	0	15,840.47	1,437,587.79	28,751.76
34	235,951	76,215.82	8,652.54	0	16,236.48	1,437,587.79	28,751.76
35	234,771	77,730.61	8,868.85	0	16,642.39	1,437,587.79	28,751.76
36	233,597	79,275.50	9,090.57	0	17,058.45	1,437,587.79	28,751.76
37	232,429	80,851.10	9,317.83	0	17,484.92	1,437,587.79	28,751.76
38	231,267	82,458.02	9,550.78	0	17,922.04	1,437,587.79	28,751.76
39	230,111	84,096.87	9,789.55	0	18,370.09	1,437,587.79	28,751.76
40	228,960	85,768.30	10,034.29	0	18,829.34	1,437,587.79	28,751.76
41	227,815	87,472.94	10,285.15	0	19,300.07	1,437,587.79	28,751.76

42	226,676	89,211.47	10,542.27	0	19,782.58	1,437,587.79	28,751.76
43	225,543	90,984.55	10,805.83	0	20,277.14	1,437,587.79	28,751.76
44	224,415	92,792.86	11,075.98	0	20,784.07	1,437,587.79	28,751.76
45	223,293	94,637.12	11,352.88	0	21,303.67	1,437,587.79	28,751.76
46	222,177	96,518.03	11,636.70	0	21,836.26	1,437,587.79	28,751.76
47	221,066	98,436.33	11,927.62	0	22,382.17	1,437,587.79	28,751.76
48	219,960	100,392.75	12,225.81	0	22,941.72	1,437,587.79	28,751.76
49	218,861	102,388.06	12,531.45	0	23,515.27	1,437,587.79	28,751.76
50	217,766	104,423.02	12,844.74	0	24,103.15	1,437,587.79	28,751.76

Net Salvage Value	Operating Costs	Deductible Expenses	State IBI	Total IBI	State PBI	Total PBI	Federal ITC
0	0	0	52,500	52,500	0	0	
0	39,770.20	-39,770.20			61,246.68	61,246.68	431,276.34
0	40,045.66	-40,045.66			62,159.25	62,159.25	
0	40,328.01	-40,328.01			63,085.43	63,085.43	
0	40,617.41	-40,617.41			64,025.40	64,025.40	
0	40,914.05	-40,914.05			64,979.38	64,979.38	
0	41,218.11	-41,218.11			65,947.57	65,947.57	
0	41,529.77	-41,529.77			66,930.19	66,930.19	
0	41,849.22	-41,849.22			67,927.45	67,927.45	
0	42,176.66	-42,176.66			68,939.57	68,939.57	
0	42,512.28	-42,512.28			69,966.77	69,966.77	
0	42,856.29	-42,856.29			0	0	
0	43,208.91	-43,208.91			0	0	
0	43,570.34	-43,570.34			0	0	
0	43,940.80	-43,940.80			0	0	
0	44,320.53	-44,320.53			0	0	
0	44,709.74	-44,709.74			0	0	
0	45,108.69	-45,108.69			0	0	
0	45,517.62	-45,517.62			0	0	
0	45,936.76	-45,936.76			0	0	
0	46,366.39	-46,366.39			0	0	
0	46,806.76	-46,806.76			0	0	
0	47,258.13	-47,258.13			0	0	
0	47,720.79	-47,720.79			0	0	
0	48,195.02	-48,195.02			0	0	
0	48,681.10	-48,681.10			0	0	
0	49,179.33	-49,179.33			0	0	
0	49,690.02	-49,690.02			0	0	
0	50,213.48	-50,213.48			0	0	
0	50,750.02	-50,750.02			0	0	
0	51,299.98	-51,299.98			0	0	
0	51,863.68	-51,863.68			0	0	
0	52,441.48	-52,441.48			0	0	
0	53,033.72	-53,033.72			0	0	
0	53,640.77	-53,640.77			0	0	
0	54,263	-54,263			0	0	
0	54,900.78	-54,900.78			0	0	
0	55,554.50	-55,554.50			0	0	
0	56,224.57	-56,224.57			0	0	
0	56,911.39	-56,911.39			0	0	
0	57,615.39	-57,615.39			0	0	
0	58,336.98	-58,336.98			0	0	

0	59,076.61	-59,076.61	0	0	
0	59,834.73	-59,834.73	0	0	
0	60,611.80	-60,611.80	0	0	
0	61,408.30	-61,408.30	0	0	
0	62,224.72	-62,224.72	0	0	
0	63,061.54	-63,061.54	0	0	
0	63,919.29	-63,919.29	0	0	
0	64,798.47	-64,798.47			0
0	65,699.64	-65,699.64			0

State Depreciation	State Depreciat	State Income Ta	State Tax Savings	Federal Depreciation Schedule (%)	Federal Depreciation	Federal Income Taxes
0	0	0	0	0	0	0
20	244,389.92	-11,928.94	11,928.94	20	244,389.92	-44,375.66
32	391,023.88	-25,823.72	25,823.72	32	391,023.88	-96,064.24
19.2	234,614.33	-14,829.98	14,829.98	19.2	234,614.33	-55,167.54
11.52	140,768.60	-8,215.24	8,215.24	11.52	140,768.60	-30,560.70
11.52	140,768.60	-8,169.23	8,169.23	11.52	140,768.60	-30,389.53
5.76	70,384.30	-3,195.84	3,195.84	5.76	70,384.30	-11,888.52
0	0	1,778.03	-1,778.03	0	0	6,614.27
0	0	1,825.48	-1,825.48	0	0	6,790.77
0	0	1,873.40	-1,873.40	0	0	6,969.06
0	0	1,921.81	-1,921.81	0	0	7,149.15
0	0	-2,999.94	2,999.94	0	0	-11,159.78
0	0	-3,024.62	3,024.62	0	0	-11,251.60
0	0	-3,049.92	3,049.92	0	0	-11,345.72
0	0	-3,075.86	3,075.86	0	0	-11,442.18
0	0	-3,102.44	3,102.44	0	0	-11,541.06
0	0	-3,129.68	3,129.68	0	0	-11,642.42
0	0	-3,157.61	3,157.61	0	0	-11,746.30
0	0	-3,186.23	3,186.23	0	0	-11,852.79
0	0	-3,215.57	3,215.57	0	0	-11,961.93
0	0	-3,245.65	3,245.65	0	0	-12,073.81
0	0	-3,276.47	3,276.47	0	0	-12,188.48
0	0	-3,308.07	3,308.07	0	0	-12,306.02
0	0	-3,340.46	3,340.46	0	0	-12,426.49
0	0	-3,373.65	3,373.65	0	0	-12,549.98
0	0	-3,407.68	3,407.68	0	0	-12,676.56
0	0	-3,442.55	3,442.55	0	0	-12,806.30
0	0	-3,478.30	3,478.30	0	0	-12,939.28
0	0	-3,514.94	3,514.94	0	0	-13,075.59
0	0	-3,552.50	3,552.50	0	0	-13,215.31
0	0	-3,591	3,591	0	0	-13,358.51
0	0	-3,630.46	3,630.46	0	0	-13,505.30
0	0	-3,670.90	3,670.90	0	0	-13,655.76
0	0	-3,712.36	3,712.36	0	0	-13,809.98
0	0	-3,754.85	3,754.85	0	0	-13,968.06
0	0	-3,798.41	3,798.41	0	0	-14,130.08
0	0	-3,843.05	3,843.05	0	0	-14,296.16
0	0	-3,888.82	3,888.82	0	0	-14,466.39
0	0	-3,935.72	3,935.72	0	0	-14,640.88
0	0	-3,983.80	3,983.80	0	0	-14,819.73
0	0	-4,033.08	4,033.08	0	0	-15,003.05
0	0	-4,083.59	4,083.59	0	0	-15,190.95

0	0	-4,135.36	4,135.36	0	0	-15,383.55
0	0	-4,188.43	4,188.43	0	0	-15,580.96
0	0	-4,242.83	4,242.83	0	0	-15,783.31
0	0	-4,298.58	4,298.58	0	0	-15,990.72
0	0	-4,355.73	4,355.73	0	0	-16,203.32
0	0	-4,414.31	4,414.31	0	0	-16,421.23
0	0	-4,474.35	4,474.35	0	0	-16,644.58
0						
0						

Federal Tax Savings	After Tax Cost	After Tax Cashflow	Payback	Cumulative payback
0	-1,385,087.79	-1,385,087.79	-1,385,087.79	-1,385,087.79
475,652	509,057.42	535,714.42	535,714.42	-849,373.36
96,064.24	144,001.55	171,188.36	171,188.36	-678,185
55,167.54	92,754.94	120,482.09	120,482.09	-557,702.91
30,560.70	62,183.93	90,462.16	90,462.16	-467,240.75
30,389.53	62,624.08	91,464.34	91,464.34	-375,776.41
11,888.52	39,813.82	69,227.27	69,227.27	-306,549.13
-6,614.27	17,008.12	47,006.17	47,006.17	-259,542.96
-6,790.77	17,461.98	48,056.24	48,056.24	-211,486.72
-6,969.06	17,920.44	49,122.77	49,122.77	-162,363.95
-7,149.15	18,383.52	50,205.99	50,205.99	-112,157.96
11,159.78	-28,696.57	3,758.37	3,758.37	-108,399.60
11,251.60	-28,932.68	4,167.30	4,167.30	-104,232.30
11,345.72	-29,174.70	4,583.15	4,583.15	-99,649.15
11,442.18	-29,422.76	5,006.02	5,006.02	-94,643.13
11,541.06	-29,677.02	5,436.03	5,436.03	-89,207.10
11,642.42	-29,937.65	5,873.28	5,873.28	-83,333.82
11,746.30	-30,204.78	6,317.88	6,317.88	-77,015.94
11,852.79	-30,478.60	6,769.96	6,769.96	-70,245.98
11,961.93	-30,759.26	7,229.61	7,229.61	-63,016.37
12,073.81	-31,046.93	7,696.96	7,696.96	-55,319.41
12,188.48	-31,341.80	8,172.13	8,172.13	-47,147.28
12,306.02	-31,644.04	8,655.23	8,655.23	-38,492.05
12,426.49	-31,953.84	9,146.38	9,146.38	-29,345.67
12,549.98	-32,271.38	9,645.70	9,645.70	-19,699.96
12,676.56	-32,596.86	10,153.33	10,153.33	-9,546.64
12,806.30	-32,930.48	10,669.37	10,669.37	1,122.73
12,939.28	-33,272.44	11,193.96	11,193.96	12,316.69
13,075.59	-33,622.94	11,727.22	11,727.22	24,043.91
13,215.31	-33,982.21	12,269.29	12,269.29	36,313.20
13,358.51	-34,350.46	12,820.29	12,820.29	49,133.49
13,505.30	-34,727.92	13,380.35	13,380.35	62,513.83
13,655.76	-35,114.82	13,949.60	13,949.60	76,463.44
13,809.98	-35,511.38	14,528.19	14,528.19	90,991.63
13,968.06	-35,917.86	15,116.25	15,116.25	106,107.88
14,130.08	-36,334.50	15,713.91	15,713.91	121,821.79
14,296.16	-36,761.56	16,321.32	16,321.32	138,143.11
14,466.39	-37,199.30	16,938.60	16,938.60	155,081.71
14,640.88	-37,647.97	17,565.92	17,565.92	172,647.63
14,819.73	-38,107.87	18,203.40	18,203.40	190,851.02
15,003.05	-38,579.26	18,851.19	18,851.19	209,702.21
15,190.95	-39,062.44	19,509.44	19,509.44	229,211.66

15,383.55	-39,557.70	20,178.30	20,178.30	249,389.96
15,580.96	-40,065.33	20,857.92	20,857.92	270,247.88
15,783.31	-40,585.66	21,548.44	21,548.44	291,796.32
15,990.72	-41,119	22,250.02	22,250.02	314,046.34
16,203.32	-41,665.67	22,962.81	22,962.81	337,009.14
16,421.23	-42,226.01	23,686.96	23,686.96	360,696.10
16,644.58	-42,800.35	24,422.63	24,422.63	385,118.73
0	-4,535.89	4,535.89		0
0	-4,598.97	4,598.97		0

Appendix 10

Site Planning for Area O

Existing Conditions Site Plan
West Fuala Plant Expansion
Abu Dhabi, PA

Appendix E

Jaafar Al Aidaroos
03/16/2012

Legend

- DUMPSTER
- FENCE
- CRANE
- Bathroom/ Locker Area