Senior Thesis Final Report

C O N S T R U C T I O N M A N A G E M E N T

Landis Run Intermediate
Lancaster, Pennsylvania

Presented By Matthew Stevenson
Advisor: Dr. Robert Leicht

April 4th, 2012

Landis Run Intermediate School

Lancaster, PA

Matthew Stevenson | Construction Management

Project Team

Owner: Manheim Township School District

Architect: Crabtree, Rohrbaugh & Associates

General Contractor: Warfel Construction

Mechanical Constractor: Frey Lutz

Electrical Contractor: MBR Construction Services

Plumbing Contractor: J.R. Reynolds

Low Voltage Contractor: Lobar Inc.

Structural System

Foundation: Continuous Footings w/ 3000 PSI Compressive Strength

Walls: Load Bearing Ivany (2000 PSI) & Standard (1500 PSI) Masonry

Decks: Concrete (3500 PSI) on Composite Metal Decking (40 KSI)

Classroom Live Load: 40 PSF

Partial Steel Frame in Area B on Column Piers

Total Load = DL + LL = 55 PSF + 40 PSF = 95PSF

Electrical/Lighting System

Capacity: 2500A

Distribution Panel 1: 120/208 V (Outlets)

Distribution Panel 2: 277/480V (Lighting & Other)

Redundancy: 130 KW Natural Gas Generator w/ UPS

Lighting: Majority are CFL & T8 Lamps

Building Statistics

Size: 210,000 SF

Height: 1 & 3 stories

Project Cost: $28,400,000

Project Type: Educational

Contract Type: Multiple Prime

Duration: Approximately 20 Months

Purpose: Accommodation of Increased Demand

LEED Goal: Silver

Envelope System

Veneer: Four Layers of Decorative CMUs At Base of Wall w/ Brick Above

Anchor: Two Piece Anchor

Curtain Wall: Comprised of Various Glazing Types & Aluminum Mullions

Roof: Single-Ply White EPDM & TPO Roofing

Insulation: Spray Foam Insulation w/ R-Value of 7 At 1" Thick

Mech./Fire Protection System

System Type: Variable Air Valve

Number of AHUs: Nine

Fire Protection System: Wet

Water Supply: Six Large Precast Concrete Tanks

Executive Summary

Geothermal Heat Pump Analysis

The quantity, construction impact, layout, and on-site place of geothermal heat pumps were identified as based on the maximum capacity of the air handling units. A general estimate was performed on the major components of the existing system and geothermal system in order to obtain a general idea of what the cost difference would be in switching to a geothermal system. In addition, a LEED analysis was performed to identify how switching to a geothermal system would affect the building's LEED rating. The analysis found that the geothermal system would not significantly affect constructability or schedule. It would increase the cost of the mechanical contract by 18.4% and the overall construction cost by 3.4%. It also found that the geothermal system would increase the LEED rating of the building from silver to gold.

Mechanical Breadth

The original intent of this breadth was to calculate any possible reduction in size of the existing mechanical equipment with the addition of geothermal heat pumps. It was discovered in Analysis 1 that the addition of geothermal heat pumps would allow the elimination of the existing mechanical equipment altogether.

Standardized Modular Classroom Analysis

The classroom wings were broken up into modules and the total quantity of modules was determined. Through discussions with industry professionals, estimates of cost savings per square foot and modules set per day were determined. From these estimate the costs savings and duration of module construction was calculated. The analysis found that utilizing modular construction would save 14.1% of the overall construction cost and would accelerate the substantial completion date of the classroom wings by nearly a year. In addition, codes regarding classroom design for the state of Pennsylvania were analyzed and it was determined that all Pennsylvania schools had to conform to the same codes. It was determined that all Pennsylvania schools could utilize the same classroom design by adjusting the number of modules used or by adjusting the modules themselves. Standard configurations for different size classrooms were presented.

Acoustical Breadth

An analysis of noise reduction capability of the existing wall assembly between classrooms and the proposed metal stud wall assembly was performed. It was shown that the assemblies had similar capability in the low frequency octave bands but differed significantly in the 2k and 4k bands. Although the metal stud assembly performs much less noise reduction for these octave bands it was shown that it still performed an adequate amount of noise reduction for the classroom spaces to be sufficiently isolated from one another.

Electrical Rough-In Method Analysis

The electrical rough-in method, underground, was analyzed and compared with overhead rough-in. An estimate of duration and cost was performed for both methods. It was determined that utilizing OH rough-in could have saved the activity 35 working days as well as $50,000. In addition, a schedule analysis was performed using the new duration of OH rough-in and it was determined that it would have accelerated the dry-in dates of each area by an average of 23 days.

Project Delivery Method Analysis

An analysis of the Pennsylvania Separations Act of 1913 was conducted to determine whether or not there were any loopholes or other ways that contractors could deliver a project in which the government was the owner by any means other than multiple prime. It was shown that it is possible when the owner is the department of general services, a borough, a township, a county, a second-class township, or a third class city. The contractor has no influence over the decision when the owner is the department of general services. For all other state owners it was determined that the project must be delivered in a multiple prime delivery method.

Credits/Acknowledgements

Academia Acknowledgements:

Dr. Robert Leicht
Dr. Moses Ling
Dr. Linda Hanagan
All Penn State AE Faculty

Industry Acknowledgements:

Warfel Construction
Crabtree, Rohrbaugh & Associates
MBR Construction Services

Special Thanks To:

Brett Calabretta
Kyle Goodyear
John Hess
Jim Spence
Joshua Bower
Manheim Township School District
Family and Friends

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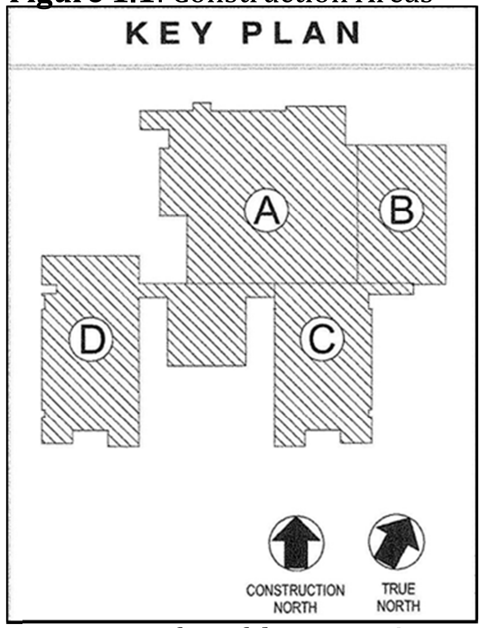
Project Overview

Introduction

Landis Run Intermediate Center is a 210,000 SF school located in Lancaster, PA which will serve grades 5 and 6 in the Manheim Township School District. The total construction cost for the project is approximately $26.4 million. The notice to proceed was given on December 10th, 2010 and site work began just five days later. The project has an anticipated completion date of August 28th, 2012.

Figure 1.1: Construction Areas



Courtesy of Warfel Construction

The building contains: 48 classrooms; 2 Science, Technology, Engineering, and Mathematics (STEM) labs; 14 small group instruction classrooms; 2 art classrooms; 1 media center; 2 music classrooms; 1 band room; 1 orchestra room; 2 P.E. classrooms; 1 two court gymnasium which doubles as the auditorium with a stage, 1 cafeteria to seat 400 students and 1 administrative suite. The building itself was split into four areas for construction purposes as shown in Figure 1.1. Area A houses the administrative suite, gym and cafeteria. Area B houses the music suite and the P.E. classrooms. Areas C and D are classroom wings. Area D also includes the library which is located inbetween the wings C and D. The classroom wings are three stories while areas A nd B are one story with the exception of the gymnasium.

Figure 1.2: West Elevation

Courtesy of Warfel Construction

The school is one of four school buildings on a large campus, which is surrounded by homes located on the other side of a landscape buffer. The building used the existing grade differential to offset the distance the students would need to travel by placing the second floor of the classroom wings at the ground level of the rest of the school as shown in Figure 1.2. The building is striving for LEED Silver certification. The project will utilize a combination of design features and construction practices in order to achieve the LEED Silver rating.

Client Information

The owner of the project is the Manheim Township School District. The township is composed of mostly middle class and upper middle class constituents. They are constructing the building in order to prepare for the growth that the district is currently experiencing as well as any anticipated growth in the future. The new 5th and 6th grade school will allow the district to expand its services, specifically the addition of full day kindergarten.

The school district's number one goal is ensuring the turnover deadline is met. It has set a strict deadline for building turnover for August 28th, 2012 so that the building will be ready for occupancy for the 2012-2013 academic year. It is an essential goal because they have no alternative locations to place the 5th and 6th grade students scheduled to occupy the building.

The second most important goal for the district is staying on budget. So far the project is actually under budget and it is important to the district that it stays that way. The board recognizes that the money being spent is taxpayer dollars and should be spent responsibly.

The district is also striving to minimize the impact on the surrounding area. The site is surrounded by houses on three sides. In recognition of this and a township noise ordinance the district has restricted construction starting time to 7 am sharp. No loud noises before this time will be tolerated. Another example of the district's commitment to not disturbing the township is the tire wash station at the exit of the site to prevent the tracking of mud onto the township roads.

Local Conditions

Landis Run Intermediate School is located in Lancaster, Pennsylvania. Although there are many common types of construction in the area, the most common method of construction is load bearing masonry. All of the contractors on site are very experienced with that type of construction and have worked on projects utilizing that type of construction before.

The site contains a sufficient amount of parking available to workers which negated the need for any off-site parking. Prior to the paving of the parking lots there was enough space for two lanes of parking in front of the job trailers of the primes. In addition, the access road, which is of substantial length, is wide enough for parking on one side. There are also many open areas that when

Figure 1.3: Aerial View of LRI

Courtesy of Warfel Construction

not being used for storage could be utilized for parking. Furthermore, the parking lots, which are of substantial size and can be seen in Figure 1.3, have recently been paved and can accommodate most of the workers.

According to the Geotechnical report provided by the owner there are approximately six different soil types on the site. In general, the soil contained variable amounts of sand and rock fragments and is generally firm, stiff, and compactible. Under normal conditions the soil found on site is suitable for construction. In addition, the Geotechnical report states that there was no groundwater found during any excavations of test pits.

Project Delivery Method

The project delivery system for Landis Run Intermediate School is multiple prime which was the only possible delivery system for the project because by law any project for which state and/or federal funds account for more than 50% of the funding must be Design-Bid-Build projects. Figure 1.4 on the following page shows the major parties involved in the design and construction of LRI and their contract relationships. In this project delivery system the five prime contractors all hold an individual contract with the owner, Manheim Township School District. Although they communicate and coordinate with one another, no one prime is responsible for or controls another prime. Although, it should be noted that certain primes do hold certain responsibilities for the entire site. For instance, the GC is deemed the "lead contractor" with respect to safety and is in charge of inspecting and maintaining safe working condition on the job site, mitigating safety conflicts (i.e. when the work of one contractor puts the safety of another contractor's worker in jeopardy), and other responsibilities relating to safety. The GC is also in charge of providing and maintaining the construction schedule. In addition, the architect only holds a contract with the owner and none of the primes. Although the architect will assist in monitoring the construction process and resolving conflicts between contractors, he has no legal obligation to any of the primes or vice versa. Furthermore, any of the primes may have sub-contractors to perform parts of their contract with the owner. However, the sub-contractors only hold a contract with and only report to the prime, not the owner. In this case, the owner has a representative who monitors the progression of the project full-time. Although the owner walks the site and receives regular reports about the project, outside of occasional observation the owner is not directly involved in the project.

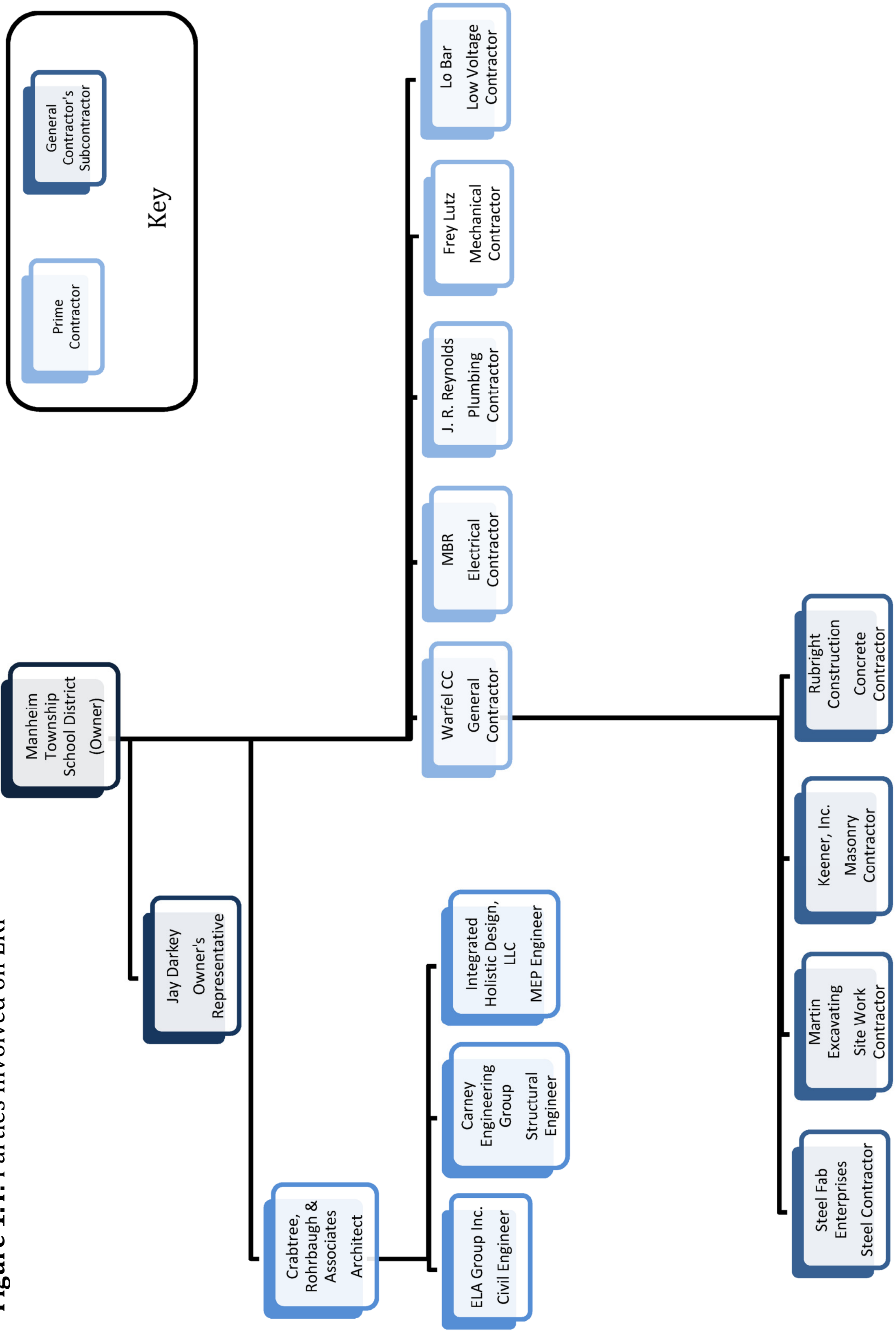


Figure 1.4: Parties Involved on LRI

General Contractor Staffing Plan

The management staff structure implemented by the General Contractor on Landis Run Intermediate School is split into two basic areas: office and field personnel. It consists of four office personnel and two field personnel. Figure 1.5 on the following page shows the structure of management of the part of the general contractor.

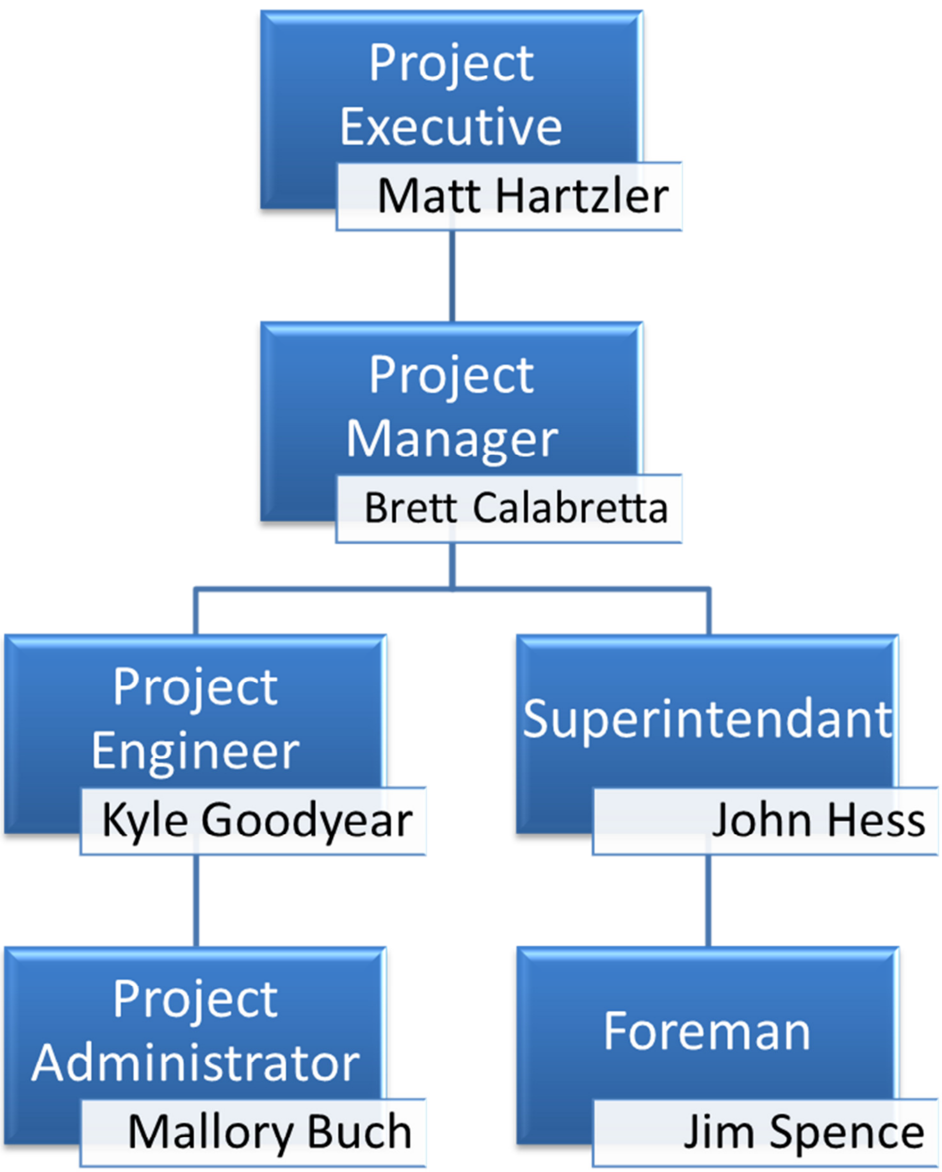
Office Personnel

The project executive analyzes and tracks the project from a broad standpoint by monitoring the overall project cost and progression of the schedule. He relies on the project manager to alert him of any major issues that may need his attention. The project executive also provides advice and information based on experience to the project manager and project engineer if something arises that they may not have much experience with. The project manager is the person who holds the highest level of responsibility for the success or failure of the project. He examines the budget and schedule on a weekly or bi-weekly basis and is constantly looking into the near future to make sure the project runs smoothly. The PM also performs and array of activities on a day to day basis that change as the project progresses. Some of these tasks include scoping bids, buying contracts, resolving conflicts with subcontractors or other contractors, as well as confronting any other issues that may arise on the project. The project engineer works hand in hand with the project manager. His main responsibilities are composing RFI's, buying out contracts, scoping out bids, writing scopes of work, staying with contact with field personnel and resolving any issues they may raise, as well as taking meeting minutes and any miscellaneous tasks they may be assigned by the project engineer. It is important to note that many of the tasks listed above are shared with the project manager and whoever completes them for a given issue or contract is decided by the project manager. The project manager delegates the work load to members of the project team that he sees fit based on time and experience. The project administrator coordinates, submits, and files all documents relating to the project such as RFIs, LOIs, and correspondence with other parties involved in the project. They may also track down any withstanding documents or correspondence that should have been submitted to the company but is still outstanding.

Field Personnel

Supervision, utilization, and activity planning of the site as well as communicating with the other prime contractors is the responsibility of the superintendent. The superintendent submits daily reports about the progress, conditions, and weather on the site as well as any delays that were experienced and why. He walks the site to ensure that the quality of work is acceptable and coordinates with his foreman if he sees anything that needs to be fixed or changed. The superintendent also looks ahead and makes sure that everything is in place so that the construction activities planned for the near future will be carried out smoothly and on time. The superintendent reports on a regular basis to the PM. He reports any major issues with the project and any concerns he may have. The foreman spends the majority of his day on the site directly supervising and communicating with other contractors and sub-contractors. He also ensures that the quality of work on the site is acceptable and that the other contractors are progressing as scheduled. He reports any concerns he may have with the superintendent.

Figure 1.5: General Contractor Staffing Plan



Building Systems Summary

Excavation

Landis Run Intermediate School was built nearly entirely on grade. It was able to do this by utilizing an existing grade differential. The only substantial excavation required was for the partial basement in Area B. It was simply excavated out of the side of a hill and was sloped back as oppose to using any sort of excavation support system. In addition, as predicted by the geotechnical report no sub-surface water was found on site and therefore no dewatering system was needed. There was no required demolition on site.

Concrete

Due to the fact that Landis Run Intermediate is a load bearing masonry wall concrete was not used as extensively as compared to a precast or cast-in-place structure. The main use of cast-in-place concrete for LRI is the building slabs which are part of the structure. The concrete binds to the metal decking to provide a composite material which resists the compression and tension forces placed on it. All of the cast-in-place concrete on LRI was placed with concrete pump trucks. No formwork is required, besides dimensional lumber for pour breaks, since they are simply poured up to the surrounding walls or steel angles which are welded to the decking. Precast concrete was utilized to a lesser extent in the building. The only significant amount of precast concrete that is being used for LRI is for lintels in which the use of steel is unnecessary such as over doors and some smaller windows.

Masonry

The building is supported by load bearing concrete masonry unit (CMU) walls, which are 8” and 16” thick and are filled with grout and rebar. A veneer made up of brick and decorative CMUs is supported by the load bearing walls as shown in Figure 1.6. Spray foam insulation is sprayed onto the exterior face of the CMU’s in the air space between the veneer and the load bearing wall. A weep system is also placed at the bottom of the airspace to allow for the efficient shedding of water from the assembly. The veneer is attached to the load bearing wall using a two piece anchor. The masons on LRI are using manual scaffolding for the majority of the walls on LRI. However, a hydraulic scaffolding system was used for the gymnasium due to its substantial height.

Figure 1.6: Exterior Wall Mock-up

Courtesy of Warfel Construction

Figure 1.7: Steel Joists in the Gymnasium

Courtesy of Warfel Construction

Steel

As stated before the building utilizes load bearing CMU walls which obviously negates the need for steel beams and columns. The main use of steel on LRI is for floor support. Steel K joists are used to support the composite deck and roof throughout the building. The largest joists, seen in Figure 1.7, are found in the gymnasium and total over 70' long. The smallest joist can be found in the hallways throughout the building. A 70 ton mobile crane is used to lift these joists onto the bearing plates which in turn rest on the load bearing walls. Once lifted into place the joists are welded to the base plates and laterally braced using steel angles to resist wind and other lateral forces. Since joists are not lifted into place every day the crane is not a permanent fixture on site and is only brought in on days which are scheduled to place joists. The crane simply finds acceptably level around of ground and extends its outriggers for added balance. A truck is pulled up alongside of the crane with the joists loaded on its bed. Once the joists are installed the crane leaves the site until it will be needed again.

Mechanical

The mechanical room in LRI is located in the North East corner of area B. It is separated from all other rooms by hallways which provide a noise buffer to the surrounding music rooms and faculty room. The system is a variable air volume system and uses a combination of rectangular metal ducks and flex ducts to distribute the air flow. Flex ducts are round ducts that are not rigid allowing them to be directed along non-linear paths. In LRI the metal ducts are used for the main branches throughout the school and the sub branches which go into the individual rooms. The flex ducts run from the sub branches to the diffusers in the rooms. This was done so that the ducts could be routed around other objects that may be in the plenum space. LRI utilizes a wet pipe fire protection system. LRI has six large precast concrete water storage tanks, seen in Figure 1.8, in the basement of area B which hold the water to supply the fire suppression system in case of a fire.

Figure 1.8: Fire Suppression Storage Tanks

Courtesy of Warfel Construction

Electrical

Landis Run Intermediate has two distribution panels. One operates at a building utilization voltage of 120/208V for its receptacles, lights, and other low voltage equipment. The other distribution panel operates at 277/480V for its higher voltage equipment. The electrical system has a total capacity of 2500A. The system is partially redundant. While not everything has backup power a 130 kW natural gas generator provides backup power for emergency lighting, essential mechanical equipment, and the fire suppression system. There is also an uninterruptible power supply (UPS) which will provide power for all essential equipment and emergency lighting during couple of minutes it will take for the generator to start up.

Environmental

Landis Run Intermediate is seeking a LEED Silver rating from the United States Green Building Councils. The strategies set to meet that standard are mix of design features and construction standards. The building will utilize a white roof to reduce the heat island effect and it will also use light shades in the parking lot to reduce light pollution in the area. In addition, it will have water efficient fixtures to reduce water consumption. Bike racks will be located on site to encourage alternative transportation to the building. There was also extensive use of rapidly renewable resources such as bamboo and low volatile organic compound materials used throughout the project. Other green construction methods were employed during the construction of the site such as diverting construction waste for recycling or reuse. Another construction method implemented was disturbing as little of the surrounding environment as possible.

Site Layout

Four site plans, which can be found at the end of this document in Appendix B show four different phases of construction at LRI. The first is the existing conditions plan which simply shows the building footprint and its varying number of stories, the site utilities, the site boundary, and the access drive. This plan is intended to show the layout of the site before any actual construction activities occur. The utilities and building footprint are shown to give an idea of the scale of the building and site as well as to identify where the utilities are. It should be noted that the site boundary is also where the site fencing is located.

The excavation phase plan shows the layout of the site as footers and any necessary grading is taking place. It shows where the job trailers for the prime contractors are located along with available parking. These trailers are the only temporary facilities on site. The plan also shows the general area where the stockpile is located. A site entrance/exit could not be shown on the plans due to the fact that it is located farther down the access drive and including it in the plans would have made the scale of the plan too small to distinguish any detail. This plan also shows the flow of traffic that workers and civilians coming to site will utilize.

The superstructure phase plan shows the layout of the site as the walls, slabs, joists, and roofs are being installed. It shows the laydown areas for each of the major trades that require it. Notice that the MEP laydown area is one big area. This is due to the fact that at this point in construction the MEP trades are simply running lines and pipes underground and through walls and therefore do not have as much to store as the main structural trades, masonry and steel. Construction traffic is also shown on this plan which shows how any construction equipment and/or vehicles will traverse the site. Notice that at the Northwest corner of the building the civilian traffic and construction traffic cross paths. This is a dangerous spot and can result in a severe accident if caution is not paid by both drivers of construction equipment as well as civilian vehicles where driving around the site. Notice that no crane is shown on site due to the fact that there is no permanent crane. As discussed before the crane is mobile and is only on site on days which require setting joists.

The finished plan shows the layout of the site as the vast majority of work has moved to the inside of the building and grading around the building is complete. Lay down areas are no longer necessary. The only storage needed are the storage trailers for materials which will later be installed in the building.

Due to the openness of the site and its relative seclusion there are no out of the ordinary safety procedures. The site is spacious enough to accommodate for all required parking and laydown areas as well as for the easy maneuvering of construction equipment.

Project Cost Evaluation

Table 1.1, shown below, shows the cost of the building construction cost, total project cost, and the cost of various building systems. Each cost is provided as a total cost and a cost per square foot (SF).

Table 1.1: Project Cost Summary

	Total Cost	Cost per Square Foot
Construction Cost	$26,400,000.00	$125.71
Total Project Cost	$28,400,000.00	$135.24
Structural System	$5,700,000.00	$27.14
Mechanical System	$4,900,000.00	$23.33
Electrical System	$2,800,000.00	$13.33
Plumbing System	$2,100,000.00	$10.00
Low Voltage System	$1,400,000.00	$6.67

LRI is a multi-prime project which means that the work for each major building system is owned by a separate contractor which holds a contract directly with the owner. The systems costs in the table above are simply the contract values for each of the primes. The construction cost is the cost of constructing the building and does not include site work or any other costs associated with the project. The total project cost is the construction cost plus the site work. There are no land purchasing costs associated with the project due to the fact that the owner already owned the land on which LRI is being constructed. In addition, according to parties involved with the project, the permitting fees are negligible due to the high amount of previous engineering and construction (i.e. existing storm water systems, etc.) on the campus on which LRI is being built.

General Conditions Estimate

The general conditions cost for the general contractor on LRI is estimated at $557,700.00 for the duration of the project. Table 1.2 is a breakdown of this estimate and can be found on the following page. As discussed in technical report one, LRI is on a relatively open site. Although it is surrounded on three sides by houses there is a substantial distance between the building and the houses. In addition, there is a thick buffer of trees in between the two. There is ample room on site to accommodate all equipment and deliveries as well as no heavy pedestrian or vehicular traffic except for the staff and builders on site. In addition, many of the general conditions costs are covered by other primes. Therefore, if the estimate looks somewhat simple it is because there are less general conditions items than what it typically needed on a more congested site or a site that is run by one contractor. Some examples of such items include overhead protection, diversion of pedestrian or vehicular traffic, additional parking or storage, and additional safety features. This explains why the general conditions cost is only 4% of the GC's contract value as oppose to the 10% that is common on most jobs.

This estimate does not include any general conditions items paid for by other primes or the owner. In addition, the estimate does not include any items that were purchased in a subcontract. All of the monthly costs were calculated by using a project duration of 20 months. The costs used were provided by Warfel Construction Company. Any costs provided as a lump sum figure were divided by 20 in order to obtain a monthly cost. In addition, any figures that were provided as a monthly cost were multiplied by 20 in order to obtain the total cost.

Table 1.2: General Conditions Estimate

	Quantity	Unit Cost per Month	Total Monthly Cost	Total Cost
Cell Phones	4	$50	$200	$4,000
Dumpsters	2	$850	$1,700	$34,000
Insurance	N/A	$550	$550	$11,000
Office Supplies/Internet	N/A	$70	$70	$1,400
Office Trailer	1	$550	$550	$11,000
Progressive Cleaning	N/A	$85	$85	$1,700
Site Fencing	N/A	$700	$700	$14,000
Small Tools	N/A	$550	$550	$11,000
Temp. Electric Hook-up	N/A	$70	$70	$1,400
Temporary Restroom Facilities	2	$117.50	$235	$4,700
Warfel Truck	1	$1,050	$1,050	$21,000
Foreman	1	$4,000	$4,000	$80,000
Superintendent	1	$9,000	$9,000	$180,000
Project Administrator	1	$625	$625	$12,500
Project Engineer	1	$4,250	$4,250	$85,000
Project Manager	1	$4,250	$4,250	$85,000
Project Executive	1	N/A	N/A	N/A
Total			**$27,885.00**	**$557,700.00**

Detailed Project Schedule

Critical Path

A detailed project schedule for LRI can be found in Appendix A. The critical path on Landis Run Intermediate, as shown in Figure 1.8, is typical of most load bearing masonry buildings in the Lancaster area. The first part of the critical path is the superstructure which includes footings, load bearing masonry walls, steel joists and angles, steel decking, and concrete slabs. These activities form the most substantial part of the critical path on LRI. As the erection of the superstructure progresses, subsequent critical path activities will trail to make the most efficient use of time on the project.

Dry-In activities, such as the installation of water proofing, insulation, doors, windows, and the brick veneer are the next part of the critical path. Since LRI is of substantial size the dry-in activities trail the superstructure in many areas, especially in the

Figure 1.8: Critical Path on LRI

classroom wings, as oppose to waiting for the superstructure to be completely done.

As the dry-in activities are being completed in a given area the overhead rough-in and ceiling grid can start to be installed. The installers have to be sure that the immediate area in which they are installing overhead rough-ins and ceiling grid is substantially dried in because any water that comes in contact with pipes and other overhead equipment will cause rust and other issues which will have to be remedied.

The entire building needs to be dried in before the finishes start to be installed because fluctuations in temperature and humidity can damage many of the finish materials. Once all of the overhead rough-in and ceiling grid activities are completed in a given area the finishes can start to be installed. Finishes on LRI include the installation of flooring, drywall, painting, millwork, casework, classroom equipment and technology, and specialty equipment in the gym, kitchen, and cafeteria.

The complete installation of all the finishes and the successful testing and commissioning of the building systems will make the building substantially complete.

Sequencing

The first activity for the building areas are the installation of the footings. Once the footings are poured the concrete bearing walls are brought up to SOG elevation and any underground MEP rough-ins are installed. The slab is then prepped and poured up to the walls which negate the need for forming. Once the slab is poured the walls are brought up to bearing height. MEP wall rough-ins will continue as door frames are installed and all the walls are completed. Base plates will be installed in the walls along with steel angles and then the joists and decking will be installed. As this occurs other carpentry items such as window blocking and moisture protection will be installed if needed. As the joists are being installed the MEP primes will start overhead rough-ins and installation of mechanical equipment including hangers, conduits, piping, etc. In the classroom wings the concrete will start being poured once the decking and angles are installed. In areas A & B the installation of the decking will allow the roof blocking, roof curbs for mechanical equipment, and roofing to start being installed. After the miscellaneous blocking has been installed the installation of the spray foam insulation and the brick veneer will start. The installation of windows will follow those two activities. Once the building has been dried in wiring and equipment tie in will occur. At the same time insulation of ducts and pipes will occur. Once all the MEP systems have completed rough in the interior finishes will begin. This includes activities such as metal stud framing, drywall, acoustical ceiling tile, paint, etc. As these trades progress the MEP systems will be finished with covers, diffusers, fixtures, and the like. As those activities are progressing other interior items will start being installed. This includes items like bathroom partitions, millwork, casework, and specialty equipment. It is easy to see why the critical path is basically the structure. Because not many interior trades completely hold up another. Once the structure is completed the large floor area allows trades to trail each other and work around each other.

As stated above, much of the time one trade will trail another to maximize time, work in different areas concurrently, and fluctuate manpower as available work varies. However, in a particular building area the interior trades will rotate around the floor due to the large floor area to stay out of each other's way. The direction in which the interior trades rotate has been different for each building area so far. It is decided by deliveries, communication with the other primes, and advice by foreman. The decision on how to rotate the interior trades is ultimately decided by the GC's superintendent. Because there are many primes the GC's superintendent often coordinates everyone to ensure efficiency and fairness.

Feasibility and Impact of Geothermal Heat Pumps (Depth 1)

Potential Opportunity

Although Landis Run Intermediate is striving for a LEED Silver rating with a total of 54 points there are a few credits that may have improved the environmental impact of the building and made sense to implement from a financial standpoint. One of these credits is on-site renewable energy. With a site as large as the one LRI sits on there are ample types of renewable energy that can be installed on site and operate successfully. Also, since schools are designed to have a life span of 50-60 years they can withstand larger payback periods. In addition, having on-site renewable energy presents another opportunity for the school district to educate the population on an ever increasingly important topic, sustainability.

Potential Solution

Due to their relatively cheap initial cost when compared with other sources of renewable energy as well as the size of the site, geothermal heat pumps appear to be the most logical choice of renewable energy for the project.

Research Goal

The goal of this research is to determine if geothermal heat pumps would improve the project based on whether or not they would provide:

- A significant cost savings to the owner in utilities cost
- A more sustainable building
- A minimal impact on the construction schedule
- A worthwhile payback period

Geothermal Heat Pumps

A geothermal heat pump is an extremely efficient and "green" method of cooling and heating a building. A geothermal heat pump consists of a liquid which flows in a loop of tubing, usually some sort of heavy duty plastic, which is placed in the ground, either vertically or horizontally, and tied into a heat exchanger within the building. The fluid within the loop can be water, a chemical such as glycol or ammonia, or a mixture of the two. What makes geothermal efficient and relatively cheap is the source of heat which also doubles and the "heat sink", the earth. No matter what the outside temperature is the earth remains a steady temperature 5-8' below the surface. This temperature varies with region and is typically 52-55 degrees Fahrenheit in the central Pennsylvania region.

On a cold day the water is pumped through the loops via pumps and absorbs the heat of the earth which is then transferred to the building space via a heat exchanger. Likewise, on a hot day the water gets cooled as it flows through the loop and is then able to absorb heat from the building space, thereby cooling it, and dump it back into the earth and it flows through the loop again.

The building's heating and cooling loads determine the total length of pipe needed to adequately cool and heat the building. The number of wells, as well as the depth of well determines the total length of pipe achieved. A number of factors affect the length of pipe needed in addition to the building loads and are discussed below.

Geothermal systems are extremely efficient when compared to its traditional competitors. A geothermal system typically has an efficiency of 300-450%. By comparison, a typical boiler only has an efficiency of about 80%. This can create a cost savings over the life span of a building particularly for buildings that are designed to be around for a long time, such as schools. In addition to saving electricity costs, geothermal systems also have relatively low maintenance costs as its components typically require less maintenance and have a longer life span, typically 50 to 75 years for the loop itself.

Lastly, these systems are much more "green" than their competitors which rely on fossil fuels. The only component of the system which requires the use of fossil fuels is the heat pumps. They rely on fossil fuels indirectly because the electricity that powers them is produced typically using fossil fuels or nuclear energy. Over the life span of a typical school, typically 50-60 years, the amount of reduced emissions through the use of geothermal systems would be enormous.

Quantity Determination

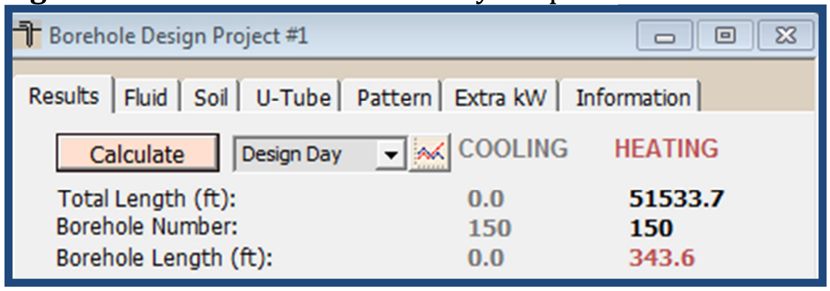
The first step in determining the feasibility and impact of geothermal heat pumps is determining the amount of wells that would be required in order to adequately satisfy the building's heating and cooling load. There are many factors that contribute to this calculation. Some of the factors included in the calculation are:

- Ground Temperature in Region
- Building Heating Load
- Building Cooling Load
- Thermal Conductivity of the Grout Surrounding Well Pipe
- Size and Spacing of Bore Holes
- Liquid used in the Pipes
- Heat Pump Used

The heating and cooling load were taken as the maximum amount of British Thermal Units (BTU's) used by the building's nine air handling units (AHUs). The building would rarely need this capacity since having all AHUs on at full capacity would represent the worst case scenario the building was designed for which will rarely, if ever, be the case. In order to determine this quantity as accurately as possible a software program, Ground Loop Design Commercial Version 2012, by GLD software was used.

Wherever definitive values for different input parameters were not available, values were chosen to be on the conservative side. The system was assumed to use 100% water in the well pipes. The ground temperature was selected as 55 degrees due to the fact that around the Lancaster area the ground temperature stays at a relatively constant 52-55 degrees year round beyond a depth of approximately 8-10 feet. The bore holes were assumed to be 5 inches in diameter with an outside pipe diameter of 1 ½" which leaves room for an inch of grout around the outside of the pipes within the bore hole. In addition, the bore holes were assumed to be spaced 20 feet apart on center. As stated above, other factors such as grout conductivity and heat pump selections were assumed and were chosen conservatively.

Figure 2.1: GLD Software Summary Output



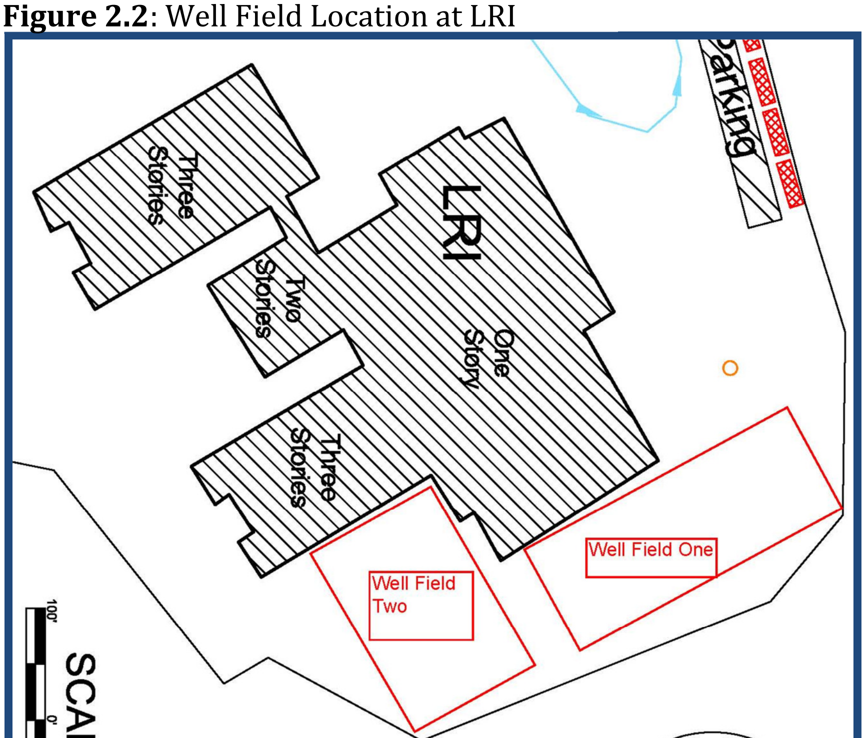
As shown in Figure 2.1, which is a screen shot of the program's summary output, LRI would require 150 wells at a depth of 343 feet.

Well Field Placement and Layout

Placing 150 wells with 20 feet in between each well requires a substantial amount of space. After site analysis, it has been determined that the site cannot accommodate all of the wells in one well field which would require an area of approximately 180' by 280'. However, the site can accommodate two separate well fields which would be in very close proximity to one another as shown in Figure 2.2. Well field one would be laid out in 14 rows of 6 with the last row only containing two wells in order to accommodate 80 of 150 wells. Well field two would be laid out with 10 rows of 7 in order to accommodate 70 of 150 wells. The layouts of the bore holes within the well fields can be seen in Figure 2.3 on the following page.

Both well fields are in close proximity to the mechanical room, located in area B, which will reduce the amount of pipe that well needed to be run to the wells and therefore reduce costs. It will also

Figure 2.2: Well Field Location at LRI



make the system more efficient by limiting the distance that the heat pump must force the water.

Some of the wells are very close to the building, within 10 to 15 feet. It was assumed that this would still satisfy the 20' spacing requirement since the foundation only goes down a few feet below grade which is negligible compared to the 343' that the wells will be descending below grade.

Construction Impact

As shown in the site layout drawings of Appendix B, the construction of the well fields would block construction traffic around this side of the building. Although inconvenient, it would not reduce construction efficiency to such an extent to warrant any significant construction delays or added cost. It would also reduce the laydown areas for steel and masonry. However, there is ample room near the soil stockpile near the south end of the building for additional laydown area.

The drilling of the bore holes does not require a significant amount of space, only the space for the drilling rig which is mounted on a truck is needed, the drilling of the bore holes, even close to the building, would not delay or disrupt foundation and slab work. In addition, the installation of the geothermal wells is not expected to increase the duration of the project due to its isolation from the other activities. However, the site contractor would most likely have to grade this area of the site sooner than he otherwise would have but that it not expected to affect other construction activities due to the flexibility in the site work schedule.

According to Warfel Construction, one a similar project in nearby Harrisburg, they were drilling two wells of similar depth per day on average. Assuming that subsurface

Figure 2.3: Well Field Layout at LRI

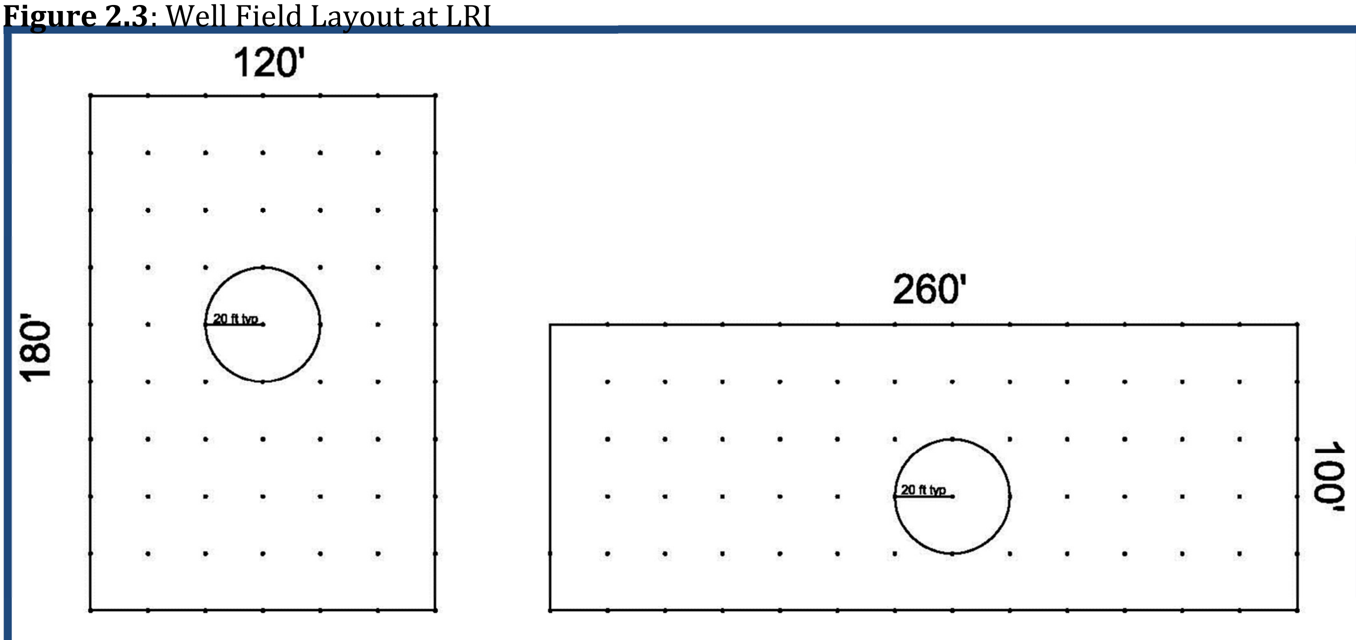
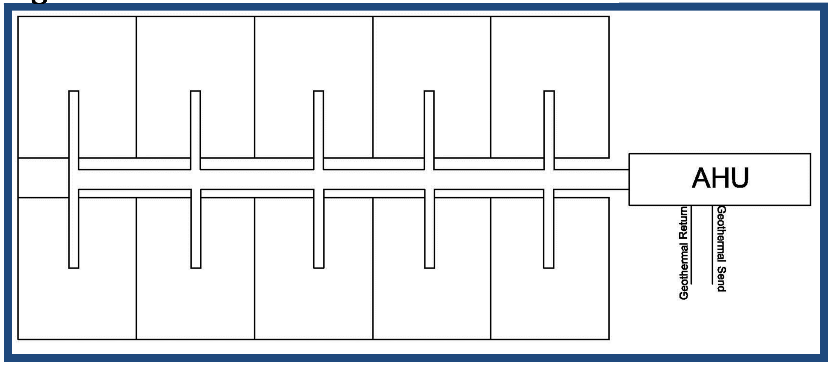


Figure 2.4: Geothermal Tie-In Method One



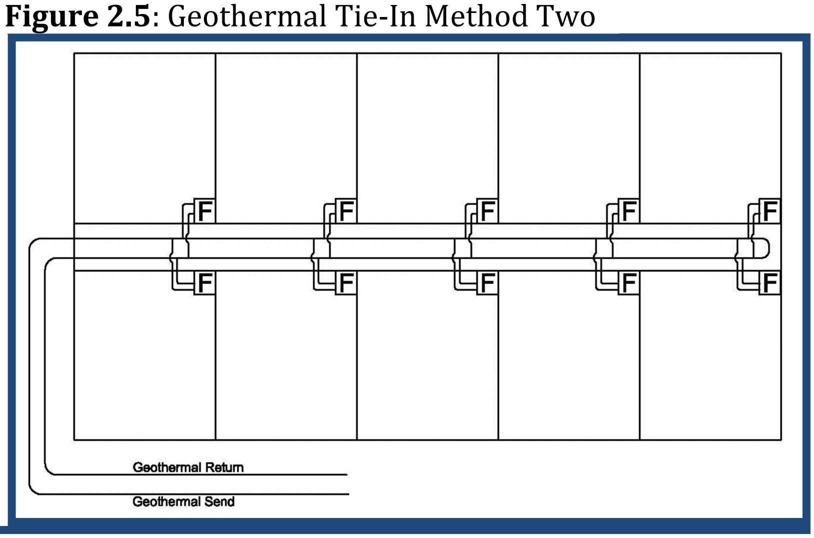
conditions and working conditions on LRI are similar to that job, which is conservative since the Harrisburg job site was vastly more congested, the drilling of all 150 wells would take 75 working days or 15 weeks. Assuming that the drilling started with the foundation work of Area C, which would be a reasonable assumption since the grading of that area would be complete, the drilling would commence on approximately 5/25/11 and finish up around 9/7/11 which would give ample time for tie-in to the building since the AHUs in areas A & B will not begin until 10/7/11 and the AHUs for areas C & D will not be set until 2/22/12. A detailed project schedule can be found in Appendix A.

System Tie-In

There are two main ways to tie geothermal systems into a building of this size. Tie-in method one, shown in Figure 2.4, would simply tie right into the existing AHUs for the building. Basically, instead of the pipes coming from boilers, the pipe come from the geothermal wells. Tie-in method two would be to not use AHUs altogether. The geothermal pipes would rather be run down the main corridors of the building and tied into individual heat exchangers, much like a furnace in a home, as shown in Figure 2.5.

There are advantages and disadvantages to each tie-in configuration. Method one will be cheaper because instead of pushing air the system is pushing water. It's always cheaper to push water because a great deal of money is saved by not buying big, bulky ducts. It can be assumed that the cost of the individual furnaces will roughly offset the cost of the nine AHUs. In addition, this method would most likely simplify MEP coordination by eliminating all the ductwork which is the largest component of MEP systems and requires the most coordination time. Installing underground pipe, while possibly adding some time to the beginning of the project, typically requires a great deal less coordination and would

Figure 2.5: Geothermal Tie-In Method Two



certainly cut time off of the MEP installation later in the project.

The disadvantage to method one is that by removing the AHUs there is no more fresh air entering the building besides the air that enters from open doors, windows, etc. This, in addition to probably not meeting indoor air quality prerequisites for LEED, could be potentially unhealthy if the building is a very tight building, meaning there is very little air penetration through small voids in the building envelope, which is usually strived for to save energy costs.

Cost Impact

The cost of any given HVAC system has a multitude of variables and decisions which can affect the final figure for better or worse. In order to get an estimate with 5% accuracy a detailed estimate of the geothermal system would have to be performed. That would require an actual system design. Both the detailed estimate and system design are both beyond the scope of this analysis. However, generalized calculations can be performed to get a rough idea of how utilizing a geothermal system might affect the cost of the HVAC system.

Looking at the HVAC system from the most general level possible and assuming tie-in method one as described above the major difference between the existing system and the geothermal system is where the heated and chilled water comes from. The major components in the existing system that supply the heated and chilled water to the AHUs are the two boilers, the chiller, and the cooling tower. The main component of the geothermal system that provides the heated and chilled water to the AHUs is the well fields, although a chiller would still be required. Assuming that when utilizing tie-in method one the difference in amount of piping is negligible and the AHUs stay the same, subtracting the cost of the boilers and the cooling tower from the mechanical prime's contract and then adding the cost of the geothermal wells could provide a rough idea of the price change resulting from implementing a geothermal system.

Table 2.1: Existing Mechanical Component's Cost

Equipment	Quantity	Cost
Electric Boiler, 2616 MBH, 218 Ton	2	$61,292
Cooling Tower, 459 Ton	1	$43,146
	Total Cost	104,438

As seen in Table 2.1, the cost of the boilers and cooling tower of the existing HVAC system is approximately $104,438. The calculations for the equipment costs can be found in Appendix E. The costs were calculated from RS Means data which can be found in Appendix D. Vertical geothermal wells typically cost $2000-$2400 per ton of capacity. Therefore, if the upper limit of that range is assumed to be the cost and calculating the ton capacity of each well, 2.8, the cost of the geothermal wells is $1,008,000. Therefore, subtracting $104,438 from the mechanical prime contract value of $4.9 million and adding the $1,008,000 million for the wells yields a new mechanical prime contract value of $5,803,562. This is a 18.4% increase over the existing contract value and a 3.4% increase over the total construction cost of the building. This calculation is show in Table 2.2. Trying to estimate the cost impact assuming tie-in method two is impossible since this would mean removing the air handlers, introducing many small furnaces, and completely changing the piping throughout the building. In order to do so with a reasonable amount of accuracy, all of those components would have to be sized which is beyond the scope of this analysis and beyond the expertise of the author. However, it is a widely held rule of thumb that it is cheaper to "push water" than it is to "push air". Therefore, it is reasonable to assume that tie-in method two would be cheaper than the value calculated above, but by how much cannot be reasonably estimated.

Table 2.2: Geothermal Estimate Calculation

Item	Add/Subtract Value
Existing Mechanical Prime Contract	$4,900,000
Cost of Boiler & Cooling Tower	-$104,438
Cost of Geothermal Wells	+$1,008,000
Total	$5,803,562
Percent Increase In Contract Value	18.4%

As stated above this is a rough calculation because it does not take into account many factors such as changes in pipe size, linear feet of pipe, quantity and size of pumps, and many other small components of each system. However, this estimate serves to show that switching to a geothermal system would be more expensive.

Even though the geothermal system would have a higher initial cost it would most likely end up saving the school district money over the lifetime of the building. Many articles state that geothermal systems typically have a payback of 5-7 years. Due to the size of the system, the payback period may be longer but it would certainly be substantially less than the designed lifespan of the building. However, the precise cost savings over the lifetime of the building could not be calculated due to lack of knowledge of what the energy demand of the building will actually be as well as what the Manheim Township School District pays for utilities.

Impact on LEED Rating

LRI is striving for LEED silver with an anticipated 44 credits totaling 52 points which can be seen in Table 2.3. A detailed LEED score card for the existing building design can be seen in Appendix C. Possibly due to using an earlier version during the design of the building, two regional priority credits, public transportation access and storm water design – quality control, were not included in the tally which brings the total credit count to 54 points.

Table 2.3: LEED Summary

LEED Category	Number of Credits	Number of Points
Sustainable Sites	10	10
Water Efficiency	5	5
Energy & Atmosphere	4	11
Materials & Resources	8	8
Indoor Environmental Quality	14	15
Innovation & Design Process	3	3
Total	44	52

Pumps are the only component of geothermal well systems that produce emissions and require the use of fossil fuels, either directly or indirectly. In addition, as stated above they require less fossil fuel and consequently emit that much less pollution per BTU than the conventional systems used today. This makes geothermal heat pumps one of the most green and sustainable heating and cooling systems available today.

Table 2.4: EAc2 Point Breakdown

% Renewable Energy	Points
1%	1
3%	2
5%	3
7%	4
9%	5
11%	6
13%	7

One of the credits that geothermal heat pumps could improve upon is EAc1, optimize energy performance. The credit is awarded for an energy cost savings as compared with a baseline model. The credit awards different point values for different percentage differences between the expected building performance and the baseline model. Although the building is already achieving the credit geothermal heat pumps can attain a higher threshold therefore increasing the number of points awarded. While the percent increase that can be obtained is unclear it is certain that the system would certainly improve upon it.

Another credit that the addition of a geothermal heating system would definitely obtain is EAc2, on-site renewable energy. This credit awards points for buildings that have on-site renewable energy supply a portion of the building's energy demand, whether that demand is its heating, cooling, or electricity. Figure 2.7 shows the breakdown of points awarded per percentage of the building's energy demand that is supplied by on-site renewable energy. Since the entire heating and cooling system is considered renewable energy by the credit it is a reasonable assumption that LRI would achieve the full 7 points for the credit.

Assuming that the project obtains all planned credits for the existing building, it is completely reasonable to assume that the project could achieve LEED Gold, which is a minimum 60 points, by utilizing geothermal heat pumps. In fact, the project would still hit LEED Gold even if there were no additional points awarded for the optimize energy performance credit since the 2 points for the two regional priority credits and the 7 points for on-site renewable energy credit would put the project at 61 points.

Mechanical System Reduction (Breadth 2)

Proposal for Breadth

The geothermal heat pumps that have been proposed to be used on the project can take a significant load off of the building's mechanical systems. The building's mechanical systems may even be able to be downsized if the load capacity of the heat pumps is significant enough. This would greatly increase the sustainability of the building since conventional mechanical equipment produce more emissions than heat pumps. Determining whether or not this is feasible and to what extent if so is the topic of my first breadth study.

Once the quantity of the geothermal heat pumps has been determined their total load capacity will be calculated. Then, their load capacity will be used to calculate the remaining total load of the building that needs to be picked up by the conventional mechanical systems in the building. Once the new load for the conventional mechanical systems is calculated new equipment will be selected to be installed in the building. Any cost savings, difference in electrical requirements, and difference in size between the mechanical equipment being installed now and the newly proposed equipment will be tabulated.

Commentary

While writing the proposal for this thesis the author had limited knowledge of geothermal systems. It was assumed that most geothermal systems, unless given great quantities of space, could not supply a building's entire heating and cooling load, especially a building as large as LRI. The vast majority of literature that was researched prior to writing the proposal was related to residential geothermal systems. Therefore, the capabilities of commercial geothermal systems were not well known.

The intent of this breadth was to determine the total load capacity of the geothermal system, which was performed in the analysis above, and perform an appropriate reduction in the size of the existing HVAC system. The new required capacity of the conventional HVAC system was to be calculated and any difference in cost, electrical requirements, and equipment size were to be reported and tallied.

As shown in the analysis above, a geothermal heating and cooling system can accommodate the entire building load of LRI. This means that not only can the existing boilers, chillers, and cooling towers be reduced in size but rather they can be eliminated entirely. This proved to be more expensive initially but the utilization of geothermal heat pumps would ultimately save the owner money in the long run due to its relatively higher efficiency than that of the conventional system.

Feasibility & Impact of a Standardized Modular Classroom (Depth 2)

Opportunity Identification

Given the seemingly identical requirements of classrooms, it seems redundant and wasteful to repeatedly redesign every classroom for a new school that is constructed. Construction budgets for schools could shrink substantially if the repetitive design of classrooms could be cut from the building process. In addition, if a common classroom design was created it might also cut construction costs as familiarity with the design increases.

Furthermore, given the highly repetitive nature of classrooms, their typical rectangular shape, and their lack of MEP complexity, classrooms are a great application of modular building and can result in many benefits to the job site.

Potential Solution

The design of a standardized modular classroom that could be shipped to the jobsite would reduce the need for design time related to classrooms and greatly reduce associated construction costs and duration. In addition, if small changes could be made to this standardized classroom to accommodate small differences in climate, site, aesthetics, and other miscellaneous differences from job to job than it could be used throughout the entire state.

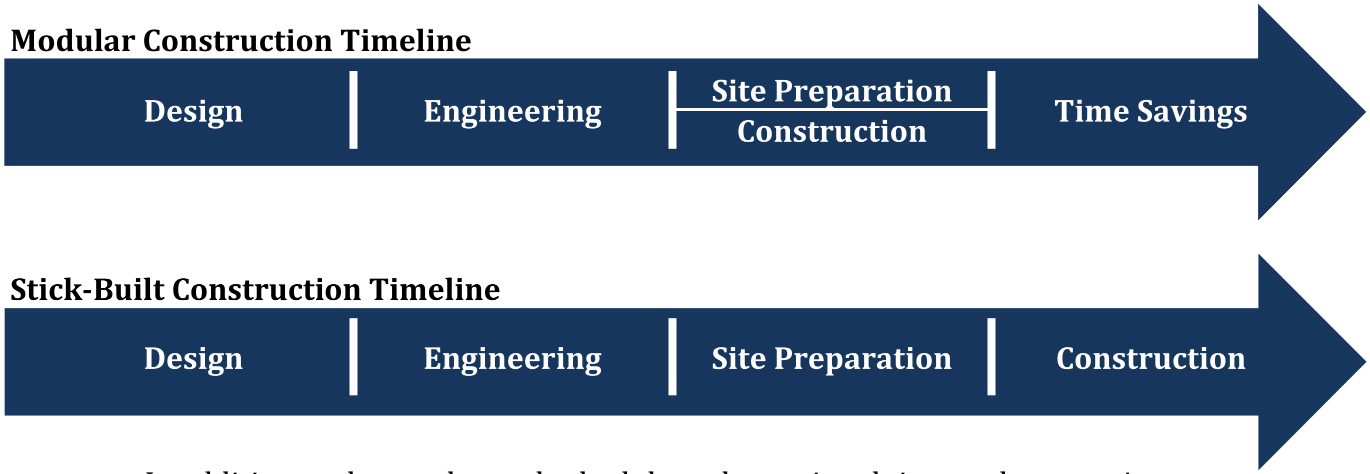
Research Goal

The goal of this research is to determine the cost and schedule implications of utilizing a modular classroom on LRI as oppose to the stick built classrooms which were constructed on site and designed specifically for this project. In addition, the analysis will research the feasibility of taking the modular classroom to be used on LRI and applying it to other schools throughout the state to determine whether or not it is feasible for the state to use a standardized modular classroom in order to save time and money on future school projects.

Benefits of Modular Construction

Modular construction offers many benefits in terms of cost, schedule, and quality of construction that stick built construction does not. In general, modular construction has a lower environmental impact, shorter on site construction duration, better quality of construction, and lower costs for the project than stick built construction. When using modular construction methods the construction of the modules is performed in a controlled environment, often in some sort of large warehouse, where temperature, humidity, and indoor air quality can be carefully controlled. In addition, it essentially allows the construction of the modules to occur while the site is still being prepped. This can result in a huge time savings when compared with stick built construction since the site would have to be prepped before the construction could begin when using stick built methods. This time savings is illustrated in Figure 3.1.

Figure 3.1: Timeline of Modular Construction vs. Stick Built Construction



In addition to the accelerated schedule and associated time and cost savings modular construction has many other benefits as well. Since the vast majority of the construction is performed off site modular construction can typically greatly reduce site disturbance due to the reduced need for equipment staging, material storage, and waste management preparations such as numerous dumpsters and waste piles. Furthermore, modular construction can reduce material waste and increase recycling due to more efficient processes that are used in the production facility as well as the absence of weather elements that can wear down or ruin building materials on site (i.e. wood warping due to moisture). In addition, modular construction typically can obtain higher tolerances since the construction is performed in a completely controlled environment. Lastly, when mechanical systems are also installed in the production facility, as is possible with classroom construction, indoor air quality can be improved. Typically, it is hard to keep all ducts from being contaminated with dust, moisture, and other elements harmful to indoor air quality for the duration of the project because the coverings used to protect the ducts can often times end up getting torn or ripped off. Due to the availability of tighter controls and prevention methods that are not possible or very difficult to achieve in stick built construction ducts can often be kept cleaner in modular production facilities which either results in better indoor air quality during occupancy or a cost savings in replacing filters and equipment before the building is occupied.

Not only can modular construction obtain the same LEED credits as stick built construction, it can generally help achieve more credits than stick built construction can. Some of the credits that are more easily achieved with modular construction as oppose to stick built construction are:

- SS Credit 5.1: Protect or Restore Habitat
- MR Credit 2: Construction Waste Management
- IEQ Credit 3.1: Construction IAQ Management Plan – During Construction
- IEQ Credit 3.1: Construction IAQ Management Plan – Before Occupancy
- IEQ Credit 10: Mold Prevention

Classroom Modules for LRI

Modular construction refers to a means of construction. Virtually any design that can be stick built can be built using modular construction. In modular construction, the design of the building is broken up into "modules" and then those modules are manufactured in a facility. They are then shipped to the jobsite and connections to the various building systems, such as structural, mechanical, plumbing, and electrical, are made.

The size of the modules is limited by the shipping process. In Pennsylvania, the modules cannot be any wider than 16 feet. This width is set for safety purposes and to ensure that the module will be able to fit down any roads it may need to travel on. The maximum length, which is set by the length of the trailers that can carry them, is about 76 feet. However, due to turning and other driving concerns it is generally advised that the modules be kept to less than 65 feet in length. The classrooms on LRI average 30 feet by 36 feet as shown in Figure 3.2.

In order to ship the modules to the site, the classrooms will have to be split into more than one module. Since the maximum acceptable module width is 16' and the length is more than either dimension of the classroom it will have to be split along its long axis as shown in Figure 3.3. This produces a classroom that is comprised of two modules that are approximately 15' by 18'. In addition, instead of using precast concrete modules which most closely mimic the load bearing masonry used on LRI, the modules will be constructed using cold formed steel, or load bearing metal studs. This will make the modules lighter which will require a lighter crane and also might allow more modules to be placed in one day.

Figure 3.2: Average Dimensions of Classroom on LRI

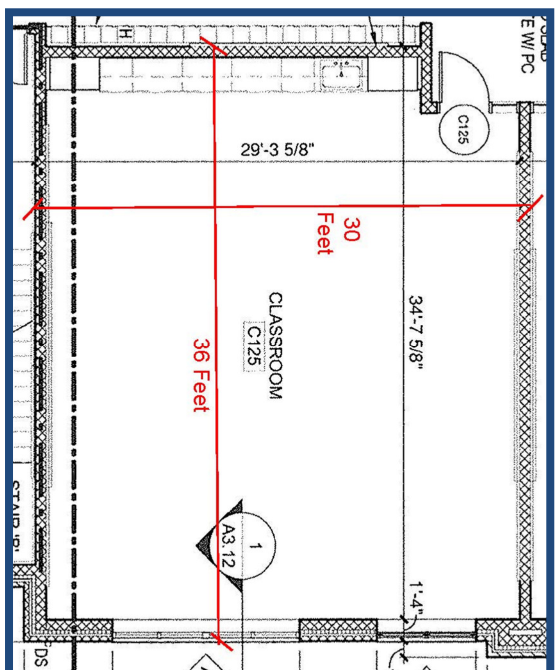
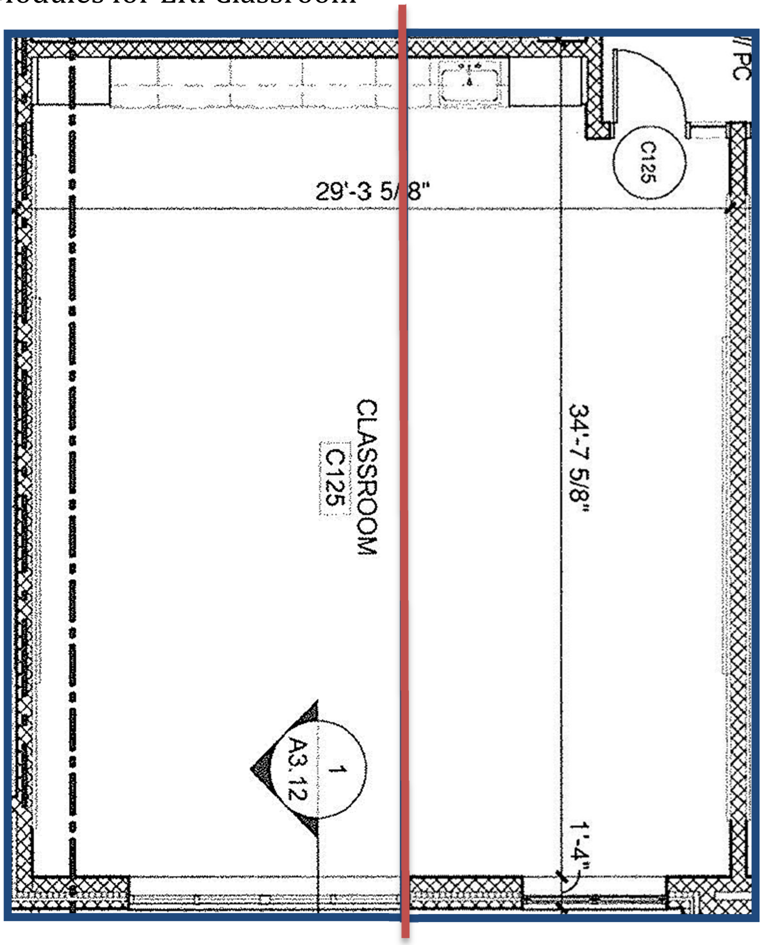


Figure 3.3: Modules for LRI Classroom



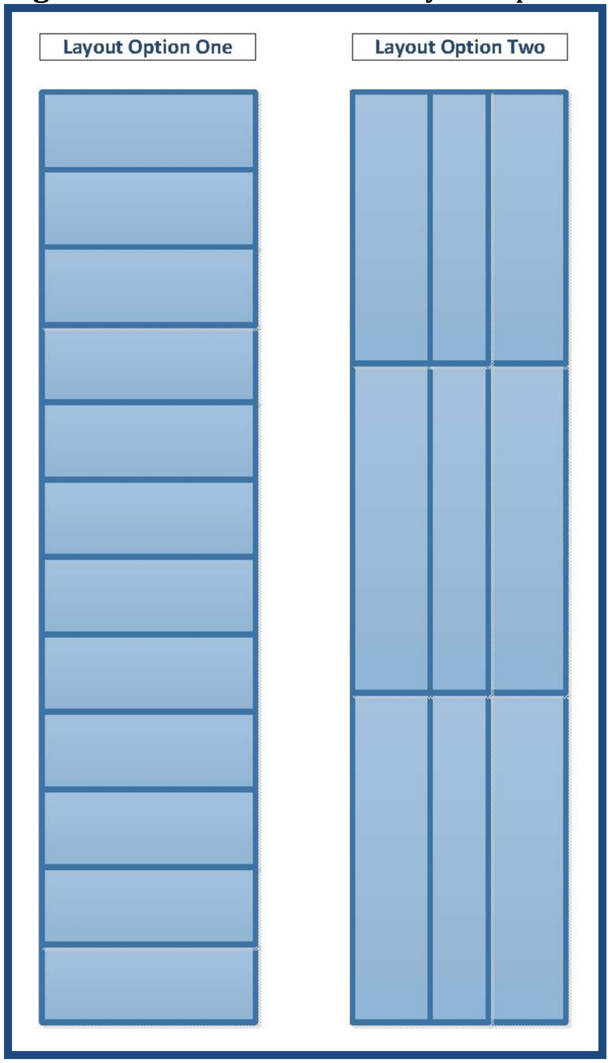
The middle section of the classroom wings which houses the lockers, two hallways, restrooms, and miscellaneous closets and other storage areas would also be constructed modularly. This area of the classroom wings is approximately 43' wide and approximately 190' long. The modules could be installed in either of two ways as shown in Figure 3.4. One option would be with one module spanning the width of the middle section. This would require 12 modules since the length of the section, 190', divided by the maximum shipping width, 16', equals 11.875. The other option would have three modules spanning the width of the section and use the maximum length allowed by shipping constraints, 65', to be used length ways along the section with the third row of modules only being 60' since the length of the wing is only 190'.

As seen from Figure 3.4 on the following page, layout option two uses less modules than layout option one does therefore taking less time to install and reducing cost. This will be the assumed layout for the remainder of the analysis.

Module Assumptions

After reviewing many different pieces of online literature it is apparent that commonly anywhere from 2-8 modules can be set per day. The actual number of modules

Figure 3.4: Interior Module Layout Options



set depends on how horizontally spread out or vertical a building is, the number of systems that are preinstalled and the number of accompanying connections that need to be made, the size of the modules, the available workforce, and the space or lack thereof on the site.

After speaking with an engineering professional from "Promise Buildings", a reputable modular construction manufacturer who commonly is involved with modularly constructing buildings similar to LRI, and discussing some of the details of the project it was agreed that it would be reasonable to assume that four modules could be set per day on average.

The factors that led to this assumption were:

- The good amount of space on site for short term storage of modules
- The limited horizontal spread of the building and its verticality
- The assumption that all systems (MEP) finishes, and casework would be preinstalled in the modules
- The assumption of a single crane
- The assumption that the workforce size would not be the controlling factor in speed
- The moderate size of the classroom modules

In terms of cost savings, many organizations such as the modular building institute and manufactures state that employing modular construction can save a project anywhere from 0%-40% of the cost per square foot depending on a multitude of factors. These factors include but may not be limited to the complexity of the building design, transportation distance and difficulty, site constraints, cost of field labor versus prefabrication labor, and the extent to which modularization was used (such as if MEP systems preinstalled as well, what percent of components such as cabinets are preinstalled, etc.).

In addition to agreeing upon a reasonable number for modules set per day on LRI, the professional at "Promise Buildings" agreed that on a building such as LRI it would be reasonable to assume a cost savings per square foot of about 20-30%. For the purposes of this analysis a cost savings of 20% per square foot will be assumed.

The factors that led to this assumption were:

- The cost savings of not having to use prevailing wages in the manufacturing process as is the case with all workers on the LRI jobsite.
- The repetitive nature of the classrooms and floor plans
- The relatively simple layout and design of the classroom wings
- The anticipated ease of delivery on the mostly open and wide roads of the area as well as good access to many different interstates and highways.
- A lack of significant site constraints
- The assumption that all systems (MEP) and the vast majority of components would be preinstalled in the modules
- The added cost of renting a crane

Impact on Construction Schedule

To review, each classroom is comprised of two modules and each interior section of the classroom wings is comprised of 9 modules per floor. Since there are 66 total rooms in the classroom wings and 6 floors between both classroom wings this gives us a total module count of:

(9 X 6 floors) + (2 x 66 floors) = 186 mod.

As stated above, it is assumed that the number of modules that can be reasonably set is 4 modules per day. With this assumption the calculated total amount of days needed to set all the modules for both classroom wings.

186 mod./ 4 (mod/day) = 46.5 days

This means that once the foundations and slab are complete for a classroom wing it will take approximately just over 23 working days, or 4.5 weeks, to install all the modules for that classroom wing. This would result in an enormous time savings for the project. Table 3.1 on the following page shows the completion dates of the classroom wings using stick-built construction and modular construction.

Table 3.1: Classroom Wing Completion Dates

Area	FRP Slab Completion Date	Stick-Built Completion Date	Modular Substantial Completion Date	Completion Date Acceleration
C	7/1/11	8/21/12	8/3/11	347 Days
D	7/28/11	8/28/12	8/30/11	363 Days

The modular substantial completion date refers to the time at which all the modules will be structural integrated and combined into one integral unit as well as when all of the preinstalled systems will be connected to one another. This date does not represent the full completion date of the classroom wings because after the modules are installed there are some minor activities to be performed such as caulking the joints between the modules, installing some of the equipment that was not able to be preinstalled such as projectors, and other final activities which will fully integrate the units and erase signs that the classroom wing was constructed modularly.

As can be seen in Table 4.1, using modular construction to construct the classroom wings would allow them to be finished almost a full year before their anticipated completion date using stick-built construction. Allow the exact amount of days would be painstaking to quantify, this would certainly allow the project as a whole to be completed much earlier than anticipated since more man power and resources could be diverted to areas A and B once areas C and D are finished. The limiting factor would then be available space in areas A and B. Considering the total monthly general conditions cost of $27,885.00 for the GC as shown in Table 1.2, even cutting a few months off of the project schedule could lead to significant cost savings to the owner and result in a higher profit margin for the prime contractors.

Impact on Construction Cost

As stated above, through discussion with an engineering professional who works at a reputable modular construction manufacturer, a reasonable estimate of cost savings per square foot on LRI is 20%. These cost savings typically come from the use of non-prevailing wage labor, a more controlled setting in the manufacturing warehouse, more efficient use of tools and materials, and a more streamlined process. As shown in Table 1.1, the construction cost of LRI per square foot is $125.71. The means that the cost of construction when utilizing modular construction would be:

$125.71 per SF * .8 = $100.56 per SF

The total square footage of the classroom wings totals 148,180 SF. The means that the cost of the classroom wings would equal:

$100.56 per SF * 148,180 SF = $14,902,166

Table 3.2 compares the cost per square foot for both stick-built and modular construction methods as well as their associated costs per square foot for the construction of areas C and D. As table 3.2 shows, and keeping in mind that the percent cost savings is an educated assumption, utilizing modular construction for the classroom wings could save LRI approximately $3.72 million dollars. The cost savings of utilizing modular construction, $3.72 million dollars, is a very significant sum of money for the project and its owners. With a building construction cost of $26.4 million, utilizing modular construction would cut the cost of the building by 14.1%.

Table 3.2: Cost Comparison of Construction Methods

	Stick-Built Construction Method	Modular Construction Method
Cost per SF	$125.71	$94.28
Total Cost	$18,622,679.40	$14,902,166

Feasibility of Statewide Usage

The program requirements of classrooms from school to school do not change very significantly. The only real variables in the programs are how many students they need to accommodate, aesthetics, finishes, and the level of technology that the school can afford and is willing to implement. For this reason, it seems very redundant and unnecessary to constantly design new classrooms for each new school project when the same design can be used and slightly adjusted for the small differences in program requirements between different schools. A classroom such as the one built on LRI could be used for every school project in PA and just adjusted slightly for each project.

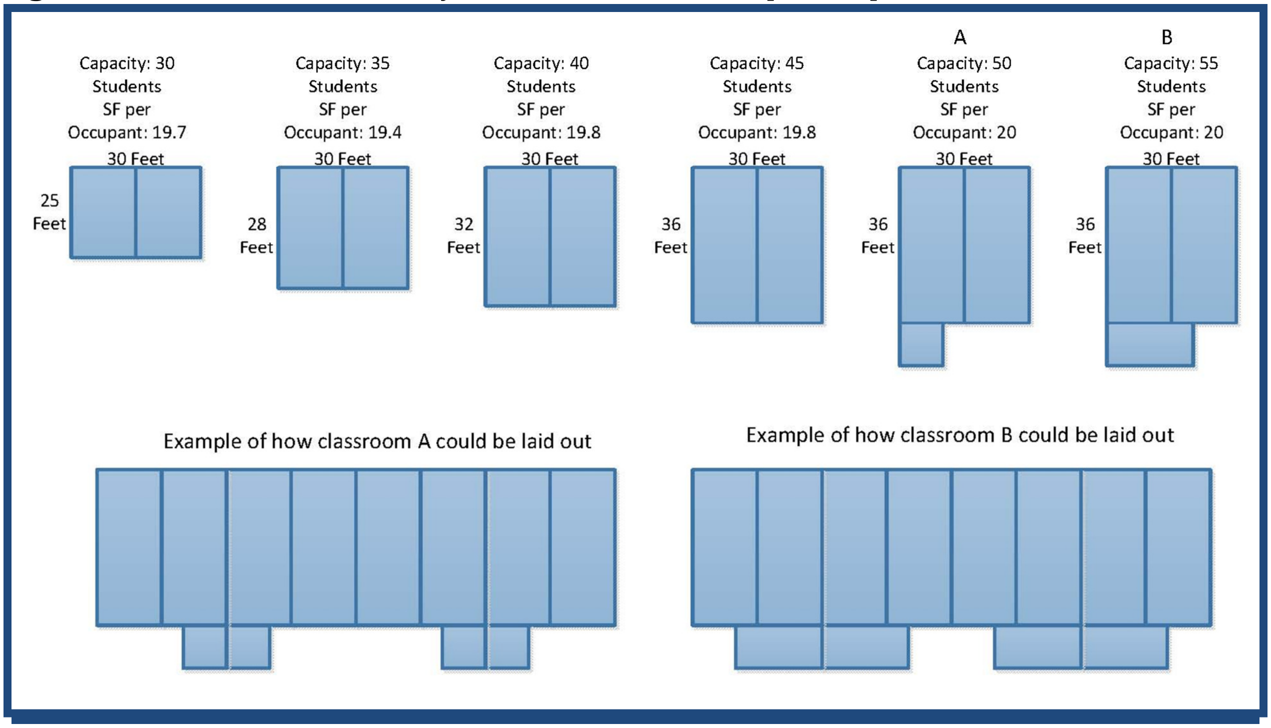
For instance, if one school utilizes projectors, such as LRI does, and another school does not, the projector system can simply be eliminated from the design since the absence of the projector system would probably not allow the feeder to the room to be downsized or for any other amount of significant redesign. Other differences such as aesthetics and finishes can be easily changed out during the manufacturing process and standard details for different exterior finishes such as brick veneer or EIFS can be created which the school could choose from.

For the majority of schools in Pennsylvania the only widely varying and significant difference in program requirements is the amount of students a classroom needs to accommodate. However, since this "standard" classroom, for which we are using the LRI classrooms as the model for the purpose of this analysis, is constructed modularly modules could simply be added or taken away for a given amount of students that need to be served.

According to the 2006 version of the International Building Code, the net maximum amount of floor area, in SF, per student that a classroom can be designed for is 20 SF. This is one of the codes that the department of education requires schools to adhere too so this requirement holds for all schools in PA. Since the net area of the classrooms on LRI are 910 SF on average, these classroom can accommodate 45 occupants. This means that for every additional 5 students a classroom needs to accommodate a module that contains 10' x 10' of net SF must be added to the classroom. Similarly, for every 10 additional students a classroom needs to accommodate a module containing 10' x 20' of net SF needs to be added. For schools that need to accommodate less than the 45 students that LRI has to accommodate, the modules can simply be shortened by certain intervals to maintain the maximum 20 SF per student requirement set forth in the IBC. Figure 3.5 shows the sizes of these smaller modules as well as a possible layout for classrooms that would need to accommodate more than 45 students.

The cost that could be saved in using the same general design throughout all of the school projects in PA could save the Department of Education as well as many school districts and immense amount of money. It could also help standardize the quality of classrooms throughout Pennsylvania and ensure that all students have access to a quality learning space.

Figure 3.5: Module Sizes and Layouts for Different Occupant Capacities



Acoustical Study of Modular Wall (Breadth 2)

Introduction

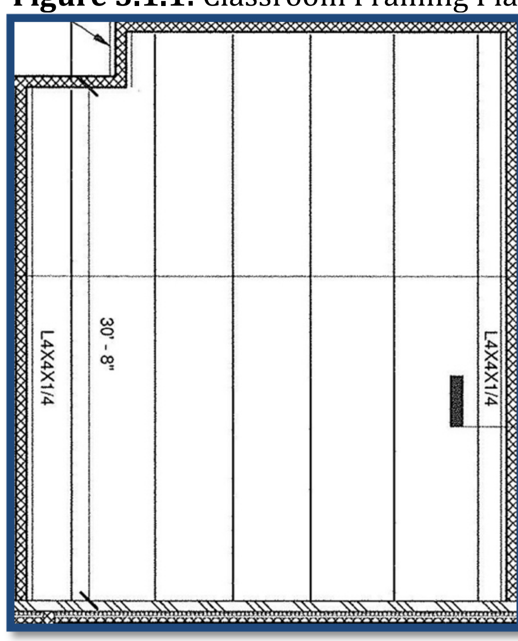
Modular construction allows for quicker and more efficient construction on site as well as a higher quality of work due to tighter tolerances in the factories. However, the design of the modules must be carefully thought out to ensure that they perform as well if not better than if the project was stick built. One of the most important aspects of a school is the learning environment is promotes. A large aspect of that is its acoustics which will determine how well the students can listen and therefore learn.

The amount of noise that passes through the metal stud walls, its Noise Reduction, of the modular classroom discussed in analysis 2 above will be calculated and compared with the amount that would pass through the load bearing masonry stick built walls being constructed to determine how the use of modular construction will affect the acoustical properties of the classrooms. In addition, the acoustical properties of the classroom will be analyzed to determine if it meets the LEED prerequisite “Minimum Acoustical Performance”. This will determine whether or not the classroom would support the LEED rating that the project is striving for.

Determining the Assembly of the Module Wall

The first step in calculating the STC of the module wall is determining what the wall will be composed of (i.e. size of metal stud, thickness of drywall, type of insulation, etc.). Many of these components have general rules of thumb that can just be assumed to be the case for our modules. However, the size of the metal stud is something that needs to be calculated for the parameters of our building.

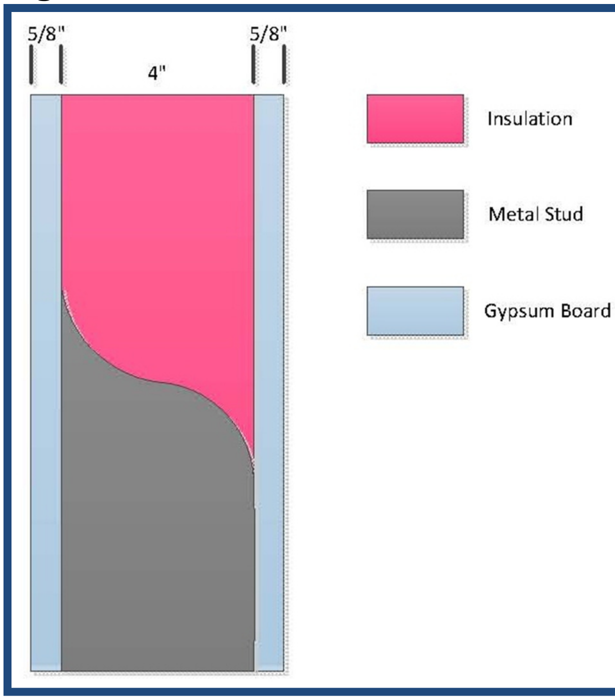
Figure 3.1.1: Classroom Framing Plan



The focus of this analysis is the noise reduction of walls between classrooms and not the walls separating the classroom from the hallways. These walls are not structural in nature since the spans run from the front of the classroom to the back as shown in Figure 3.1.1. It should be noted that this is the existing framing plan for the building which utilizes K joists. For the metal stud modular classroom the studs would run in the same orientation but would be placed at shorter intervals. It is assumed for this analysis that the studs are place every 16” O.C. A lateral load of 7.5 PSF is assumed to account for the hanging of chalkboards, other classroom equipment, as well as students pushing up against the walls. It is assumed that 33 KSI studs will be used since the wall is not structural. Lastly, since the walls are not structural we will assume that a maximum deflection of L/240 is acceptable. The difference between floors is 14 feet. Therefore, the interior walls need to span slightly less than that because six inches will be occupied by the floor above.

According to the Product Technical Information Manual from the Steel Stud Manufacturers Association, a 400S125-27 steel stud can be used for our interior partition walls. An excerpt from the manual can be seen in Figure 3.1.3. This is the student that will be used for our interior partition wall assembly. The first number in the name, 400, means that the stud is 400 1/100" deep, or 4" deep.

Figure 3.1.2: Interior Wall Section



The rest of the assembly is pretty straightforward. It will be assumed that 5/8" gypsum will be used on both sides of the wall to reduce sound transmission. Lastly, although not particularly needed for thermal insulation, the assembly will be assumed to contain insulation to further reduce the sound transmission of the wall which is a very important aspect of classrooms. Figure 3.1.2 shows a section of the interior wall that is being assumed for this analysis. It contains a cutaway of the steel studs to reveal the insulation that is assumed to be in between the studs.

Noise Reduction Calculation

The amount of decibels that are absorbed when sound passes through a wall from one room to another is known as noise reduction. The noise level in the receiving room equals the noise level in the source room minus the noise reduction for a given octave band. The formula for noise reduction at a given octave equals Transmission Loss (TL) + 10log(a/S), where a is the absorption of the receiving room and S is the area of the common wall between both the source room and the receiving room. Tables 3.1.1 and

Figure 3.1.3: Product Technical Information Manual Excerpt

Section	Fy (ksi)	Spacing (in) oc	5 psf				7.5 psf
			L/120	L/240	L/360	L/120	L/240
400S125-18 [1]	33	12	14' 9"e	14' 9"e	13' 6"e	12' 1"e	12' 1"e
		16	12' 10"e	12' 10"e	12' 3"e	10' 5"e	10' 5"e
		24	10' 5"e	10' 5"e	10' 5"e	8' 6"e	8' 6"e
		12	19' 11"	17' 10"	15' 7"	16' 3"	15' 7"
400S125-27	33	16	17' 3"	16' 2"	14' 2"	14' 1"	14' 1"
		24	14' 1"	14' 1"	12' 4"	11' 6"	11' 6"

3.1.2 show the calculations for the absorption of the receiving room for the modular assembly and existing assembly, respectively.

Table 3.1.1: Absorption Calculation for Modular Assembly

Material	Area (Ft^2)		125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Carpet, heavy	890	α	0.02	0.06	0.14	0.37	0.6	0.65
		a (sabins)	17.8	53.4	124.6	329.3	534	578.5
Drywall, 1 layer 5/8" thick	1250	α	0.55	0.14	0.08	0.04	0.12	0.11
		a (sabins)	687.5	175	100	50	150	137.5
ACT, 3/4" thick	890	α	0.76	0.93	0.83	0.99	0.99	0.94
		a (sabins)	676.4	827.7	738.7	881.1	881.1	836.6
Window	72	α	0.35	0.25	0.18	0.12	0.07	0.04
		a (sabins)	25.2	18	12.96	8.64	5.04	2.88
		Total Absorption (sabins)	1406.9	1074.1	976.26	1269.04	1570.14	1555.48

α = sound absorption coefficient a = sound absorption per specified octave

Table 3.1.2: Absorption Calculation for Existing Assembly

Material	Area (Ft^2)		125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Carpet	890	α	0.02	0.06	0.14	0.37	0.6	0.65
		a (sabins)	17.8	53.4	124.6	329.3	534	578.5
Concrete Block, Painted	1250	α	0.1	0.05	0.06	0.07	0.09	0.08
		a (sabins)	125	62.5	75	87.5	112.5	100
ACT	890	α	0.76	0.93	0.83	0.99	0.99	0.94
		a (sabins)	676.4	827.7	738.7	881.1	881.1	836.6
Window	72	α	0.35	0.25	0.18	0.12	0.07	0.04
		a (sabins)	25.2	18	12.96	8.64	5.04	2.88
		Total Absorption (sabins)	844.4	961.6	951.26	1306.54	1532.64	1517.98

α = sound absorption coefficient a = sound absorption per specified octave

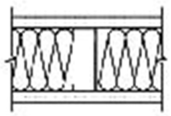
Table 3.1.3: Noise Reduction Calculations and Comparison

		125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Modular Assembly	10log(a/S)	6.17	5.00	4.58	5.72	6.64	6.60
	TL (dB)	28.00	37.00	46.00	52.00	38.00	43.00
	Noise Reduction (dB)	34.17	42.00	50.58	57.72	44.64	49.60
Existing Assembly	10log(a/S)	3.95	4.52	4.47	5.85	6.54	6.50
	TL (dB)	33.00	37.00	47.00	54.00	63.00	72.00
	Noise Reduction (dB)	36.95	41.52	51.47	59.85	69.54	78.50
	Difference	2.78	-0.48	0.89	2.13	24.90	28.89

Noise Reduction = TL + 10log(a/S), where S = Area of Common Wall and a = Room Absorption

Table 3.1.3 shows the noise reduction calculations for each assembly. The transmission losses for the assemblies were taken from "Architectural Acoustics" by David Long. They're transmission losses are shown in Figures 3.1.4 and 3.1.5. Decibel addition was performed on the data shown in the figures to convert the TL ratings from 1/3 octave band ratings to full octave band ratings. The bottom line of Table 3.1.3 shows the difference in noise reduction per octave band between the assemblies. For four of the octaves the differences are negligible. However, for the octave bands at 2000 Hz and 4000 Hz, the differences are substantial with the existing assembly reducing noise by 25 Hz and 29 Hz more at the octave bands, respectively. Human speech, probably the most notable sound that should be reduced from classroom to classroom, falls within these octave bands, or at least the majority of speech, namely consonants.

Figure 3.1.4: TL Values For Modular Wall Assembly



Single Metal Stud Wall - 3 5/8' Stud
1 Layer 5/8' Drywall Each Side
A - Without Insulation B - R-11 Batt Insulation

	125	160	200	250	315	400	500	630	800	1K	1.3K	1.6K	2K	2.5K	3.2K	4K	STC
A	20	23	30	31	30	34	40	41	45	48	49	47	39	35	40	46	39
B	29	35	40	42	43	48	52	55	57	57	57	54	45	40	44	50	44

Figure 3.1.5: TL Values For Existing Wall Assembly

8 x 8 x 16 3-cell Lightweight Concrete Masonry Unit
A No Center Grout - 28 lbs/block
B Center Grouted + #5 Rebar
C Center Grouted + #5 Rebar + 2 Coats Flat Oil Base Paint Each Side

	125	160	200	250	315	400	500	630	800	1K	1.3K	1.6K	2K	2.5K	3.2K	4K	STC
A	34	31	37	36	37	38	41	45	43	44	48	49	52	52	54	55	45
B	35	38	37	37	41	40	44	45	49	54	57	60	64	66	70	73	48
C	36	37	39	44	46	49	54	54	57	59	62	66	69	71	75	75	55

LEED Considerations

Indoor environmental quality prerequisite three states that there are two ways to comply with the prerequisite. Either "100% of all ceiling areas (except lights, diffusers, and grilles) in all classrooms and core learning spaces are finished with a material that has a noise reduction coefficient of .7 or higher" or "the total area of acoustical wall panels, ceiling finishes, and other sound-absorbent finishes equals or exceeds the total ceiling area of the room (excluding lights, diffusers, and grilles)" must be satisfied. The method of construction, modular or stick built, does not affect what materials are used. In addition, switching the classroom wings from load bearing masonry to cold formed steel studs still allows does not fore a change in ceiling material, whether it be gypsum, ACT, or some other material. In the case of LRI the ceilings are ACT. Therefore, the use of cold formed metal steel stud modules on LRI would still allow the classrooms to qualify for this prerequisite and allow the building to still obtain a LEED rating.

Underground Electrical Rough-In Method (Depth 3)

Problem Identification

The superstructure on LRI was a large part of the critical path and the project team is in a race to dry in the building before the brunt of winter hits. The electrical prime chose to do underground rough-ins for all ground floor areas of the building, including the main electrical branches, which prolonged the time before slabs could be poured and before the load bearing walls could be grouted. The decision to do underground rough-in delayed the critical path and most likely made it harder to get the building dried in before winter.

Potential Solution

Overhead electrical rough-in would have allowed slabs to be poured earlier as well as earlier grouting of walls. This in turn would allow the structure to be completed earlier which would ultimately allow the building to be dried in earlier. In addition, if overhead rough-in takes less time to perform than the overall duration of the project could have been shortened.

Research Goal

The goal of this research is to determine how changing to overhead rough-in would affect the cost and schedule of that activity and the project in general. In addition, it will also analyze how the rough-in method affects the dry-in dates for the four different areas of the building. It should be noted that the effect on MEP coordination will not be analyzed since this activity does not affect the dry-in date of the project.

Method Duration

In order to determine the difference in duration between underground rough-in and overhead rough-in, if any, I conducted interviews with the electricians on the site. I did so because I believe their estimates on duration would be more accurate than those of R.S. Means since their estimates take into account their work ethic, means, methods, and other intangibles that R.S. Means does not take into account. I interviewed all five electricians on site in order to obtain the most accurate estimate. Table 4.1 shows the electrician's estimates of duration difference for a typical classroom on LRI.

Table 4.1: Electrician Survey Results

Estimator	Estimated Duration Increase for UG RI
Electrician 1	UG by 2 hours
Electrician 2	UG by 2.5 hours
Electrician 3	UG by 1.5 hours
Electrician 4	UG by 3 hours
Electrician 5	UG by 4 hours
Average Time Increase per Classroom	**UG by 2.6 hours**

Figure 4.1: Underground Electrical Conduit

The results above indicate that the electricians estimated that on average a classroom would take 2.6 hours, or 2 hours and 36 minutes, to rough-in using the underground method as oppose to the overhead method. This is mostly due to the difference in number of tasks associated with the two methods. During underground rough-in the electrician must first lay the conduit under the stone which the slab will sit on. Often time this requires a ditch to be dug due to the size of the conduit being laid as can be seen in Figure 4.1. Then the electrician has to pull the actual wires all the way through the conduit which can be time consuming if there are multiple junction boxes or "pull points".

With overhead rough-in, MC cable can be used which is a wire that is already encased in conduit. MC cable can be ordered with different numbers of wires already inside. Therefore, overhead rough-in combines two activities into one which cuts down on the time it takes to rough in a room. Typically the MC cable is simply fastened to the walls or joists in the plenum space which is much less time consuming than digging a ditch, laying conduit, filling in the ditch, and pulling wire.

However, it should be noted that while performing underground rough in the conduits can be run in straight lines from their origin to their destination point as shown in Figure 4.1 which can reduce the amount of conduit and wire that needs to be laid. When performing overhead rough-in the cable may need to go in an indirect path so that it can be supported by suitable substrates such as joists or walls and it also may need to be routed around large obstructions such as ducts, pipes, walls, or other equipment in the plenum space.

The average size of a classroom on LRI is 975 square feet. By dividing the average estimation of duration difference for a classroom, 2.6 hours, by the square footage of the classroom, 975 ft^2, we can estimate that performing underground rough-in adds an additional 9.6 seconds per square foot to the activity. This calculation is summarized below:

2.6 Hours = 156 Min / 975 Ft^2 = .16 Min/Ft^2 * 60 Secs / 1 Min = 9.6 Secs / Ft^2

Therefore, the increase in duration from using underground rough-in as oppose to using overhead rough-in is:

9.6 Secs/Ft^2*103, 018 Ft^2 = 988,973 Secs*1 Min/60 Secs = 16, 483 Min
16, 483 Min*1 Hrs/60 Min = 275 Hrs*1 Working Day/8 Hrs = 34.5 Working Days

The calculations show that by utilizing overhead rough-in as oppose to underground rough-in the activity would have been completed approximately 35 days earlier overall. It should be noted that the full square footage of the building, 210,000 Ft^2, was not used for this calculation because underground rough-in was only performed on the ground floor of the building. Therefore, the square footage of the second and third stories of the classroom wings was not included in the calculation. The difference in duration is very significant. That's 7 full weeks of general conditions cost that the project potentially could have saved.

However, although the activity could have been performed 35 days quicker it does not necessarily mean that the project itself could have been performed 35 days quicker. One has to take into account the fact that with overhead rough in the electrical prime would be working after dry-in which is a much more congested time inside the building as many of the interior trades are also working. The presence of the electrical prime could have delayed other contractors in the same area and vice versa. These factors are very difficult to reliably quantify and are beyond the scope of this analysis but they should be kept in mind when thinking about the difference in duration for project as a whole.

Method Effect on Area Dry-In Dates

In addition to overhead rough-in taking less time to complete it also occurs at a different time in the schedule as mentioned above. Overhead rough-in occurs after the building has been dried in as oppose to during the superstructure phase of the project as is the case with underground rough-in. This is done to protect the various wires and other equipment from the elements and to prevent their corrosion and damage. By simply removing the activity from the schedule being used on LRI and moving up all trades that follow it by the duration of the rough-in activity in that area we can determine the new dry-in dates of the building. This is accurate since there are no simultaneous tasks that are also holding up the pouring of the slabs. In other words, the UG electrical rough-in was in the critical path of slab pouring and no other activities were being performed that would also hold up slab pouring with the removal of the rough-in activity. Table 4.2 shows the area dry-in dates of the actual schedule and the area dry-in dates if overhead rough-in were used. It should be noted that minor activities such as the rough-in of service to the main switchgear, which has to be done underground, is being neglected for this calculation.

Table 4.2: Dry-In Date By Method

Area	UG Dry-In	OH Dry-In Date	Dry-In Date Acceleration
A	10/6/11	9/6/11	30 Days
B	9/22/11	8/22/11	31 Days
C	2/14/12	2/2/12	12 Days
D	2/29/12	2/10/12	19 Days

As you can see from the graph the type of rough-in used can significantly affect the dry-in date since the majority of work for underground rough-in is performed prior to dry-in whereas the majority of work for overhead rough-in is performed after the dry-in date. In this particular case however, the earlier dry-in date would not particularly benefit the project in terms of avoiding winter weather. The existing dry-in dates for areas A & B are not putting those areas in danger of experiencing inclement winter weather. Furthermore, the existing dry-in dates for areas C & D are not accelerated to an extent that would bring them out of the dead of winter and reduce their risk for inclement weather. So for LRI, the difference in electrical method would not have allowed the project to better protect itself from inclement winter weather.

Method Effect on Cost

Estimate Assumptions & Accuracy

The only differences in cost between the two methods are the conduit, wire, and required installation time of the conduit and wire. All the electrical equipment stays the same and is installed in the same way. Therefore, this estimate only takes into account the conduit, wire, and installation of conduit and wire and assumes that all equipment will stay the same between either method. This means that this estimate is an estimate of any cost difference between the methods and not an estimate of the actual cost of the electrical system. By estimating the cost of the wire, conduit, and installation of both we can produce an increase in cost per SF of either method.

The cost data was retrieved from "R.S. Means Facilities Construction Cost Data 2012" and can be found in Appendix F. The total O&P costs were used for each line item which is the average billing or invoice price for that item as averaged across 30 U.S. cities. These estimates include any material, labor, equipment, overhead, and profit associated with each line item. These costs also reflect the average prevailing wage costs which accounts for the prevailing wages being employed on LRI. The cost for the trench digging labor was retrieved from the LRI specifications and reflects the hourly wage of a class 01 laborer who would typically perform activities such as digging trenches. The amount of time it takes to complete the activity was estimate based on experience by myself. The cost was adjusted to reflect differences in the average cost across 30 U.S. cities and costs around the Lancaster area. The adjustment factor, .923, was retrieved from R.S.

Means also. The cost was not adjusted for inflation since the prices were retrieved from the 2012 version from R.S. Means.

No elbows, tees, or other joints were include for the conduit since the electrical contractor on LRI was heating up the PVC conduit in order to bend it as oppose to using joints. MC cable is flexible so no joints had to be included for that conduit as well. The types of hangers used may or may not be the actual type used on the project. No splicing or cable connections were included since the runs within the classroom are sufficiently small. This may make the overall cost estimate of $50,086.71 conservative since there may be many splices and/or cable connections throughout the school. Likewise, no junction boxes or pull points were included, however, this should not affect the accuracy of the estimate since the number of junction boxes should not significantly change between either method. Again, a square footage of 103,018 SF was used as oppose to the entire 210,000 SF of the building since UG rough-in was only used on the ground floors.

The value of this estimate is not in the absolute numbers themselves but rather the difference between the numbers. It is possible that the absolute numbers may significantly deter from the actual cost of either method on LRI. This is due to the fact that often time contractors can obtain preferred pricing from vendors that are well below what the average market price may be. In addition, productivity rates could significantly differ from rates given by R.S. means since R.S. means is an average across the country and worker characteristics may significantly differ from area to area or even from company to company. However, those numbers are being applied to both estimates so the difference between the two values should be fairly accurate. In addition, the difference is what is important for this analysis.

Estimates

Table 4.3: Method Estimate

Electrical Rough-In Method Cost Difference Estimate						
Underground Method	**Cost**	**Per Unit**	**Quanity**	**Unit**	**Waste Factor**	**Total Cost**
Trench Digging, Backfilling Stone	$28.87	Hr	1.5	Hr	0	**$43.31**
PVC Conduit	$5.90	L.F.	208	L.F.	10%	**$1,349.92**
Conduit Hanger, Strap 3/4" dia.	$3.71	Ea.	18	Ea.	0%	**$66.78**
Wires	$71.50	C.L.F.	208	L.F.	5%	**$148.72**
					Total	**$1,608.73**
Overhead method	**Cost**	**Per Unit**	**Quanity**	**Unit**	**Waste Factor**	**Total Cost**
MC Cable, #12, 2 wire	$330.00	C.L.F.	240	L.F.	5%	**$831.60**
Cable Support, Clip 3/4" dia.	$2.60	Ea.	100	Ea.	0%	**$260.00**
Cable Hanger, Strap 3/4" dia.	$1.77	Ea.	2	Ea.	0%	**$3.54**
					Total	**$1,095.14**
Cost Difference Total per Classroom						**$513.59**
Location Factor						**0.923**
Adjusted Cost Difference Total per Classroom						**$474.04**
Adjusted Cost Difference Total per SF						**$0.49**
Total Cost Difference For Building						**$50,086.71**

According to the estimate above, using UG rough-in as oppose to OH rough-in for all ground floors on LRI increases the cost of the electrical system by $0.49 per SF and a total of $50,086.71 for the entire building. This is approximately .2% of the total building cost and 1.8% of the total electrical prime contract value. While is this difference may be small when compared with the total cost of the project or even with the cost of the electrical contract, it would certainly be a welcome savings to the owner and could help pay for other unforseen costs throughout the project.

Project Delivery Method Analysis (Depth 4)

Problem Identification

As mandated by the Pennsylvania Separations Act of 1913, the project delivery system on LRI was design-bid-build with multiple prime. The law requires a government entity such as a municipality or school district to seek and hold separate contracts for electrical, heating, ventilation, and plumbing work. This means that the government entity has to hold and coordinate multiple separate contracts with the individual contractors instead of simply coordinating with one individual or contractor as would be the case in other delivery systems such as single prime or construction manager at risk.

According to the general contractor's project manager, the added amount of coordination between the other primes, owner's representative, and lack of a complete authority that resulted from this type of delivery system added complexity and time to the project that could have been cut down if one contractor was in charge and had authority over the others. In addition, the few major issues, such as missing the switchgear installation date, encountered during the construction of LRI were a direct result of lack of oversight and authority within the delivery system.

Potential Solution

The single prime delivery method makes one contractor responsible for completing the project in whole. With one contractor having authority over means, methods, and scheduling, a great deal of coordination and debate can be cut out of the schedule and possibly reduce cost and increase quality.

Research Goal

There are multiple types of delivery systems charge one contractor with complete responsibility for the project. These delivery systems include the single prime, CM at risk, and Design-Build delivery systems. These delivery methods make one contractor or company responsible for completing the project in whole. With one contractor having authority over means, methods, and scheduling, a great deal of coordination and debate can be cut out of the schedule and typically reduce cost and increase quality. The goal of this research is to analyze how government funded projects can gain exemption to the Pennsylvania Separations Act of 1913 to use an alternative delivery system other than multiple prime.

The Pennsylvania Separation Act of 1913 Background

The Pennsylvania Separations Act was enacted in 1913. The act requires a government entity such as a municipality or school district to seek and hold separate contracts for electrical, heating, ventilation, and plumbing work for projects with a total cost in excess of $4,000. Just three other states, North Dakota, Illinois, and New York, in the U.S. mandate that government projects use the multiple prime delivery system, the organization of which can be seen in Figure 5.1. The law also has parallel provisions for each subdivision of the state and school code. In other words, the requirement of the law is both present as a general state law as well as part of the school code for Pennsylvania. To date, the act has been repealed for boroughs, townships, counties, second-class townships, and third class cities. Yet, the law remains applicable to public authorities and still exists in the school code.

Figure 5.1: Multiple Prime Flow Chart

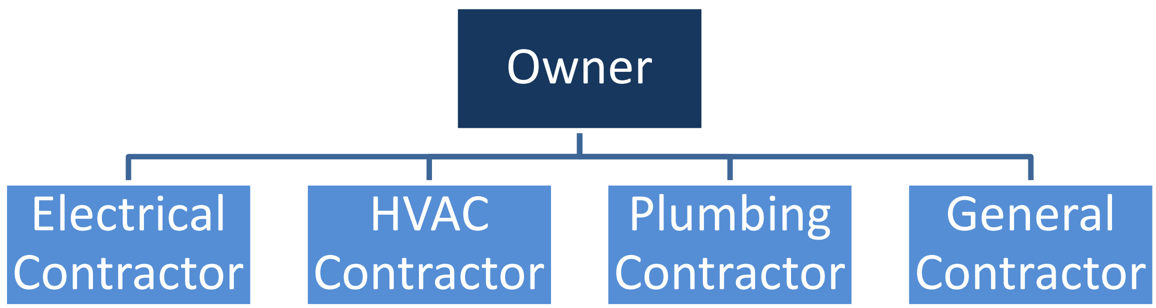
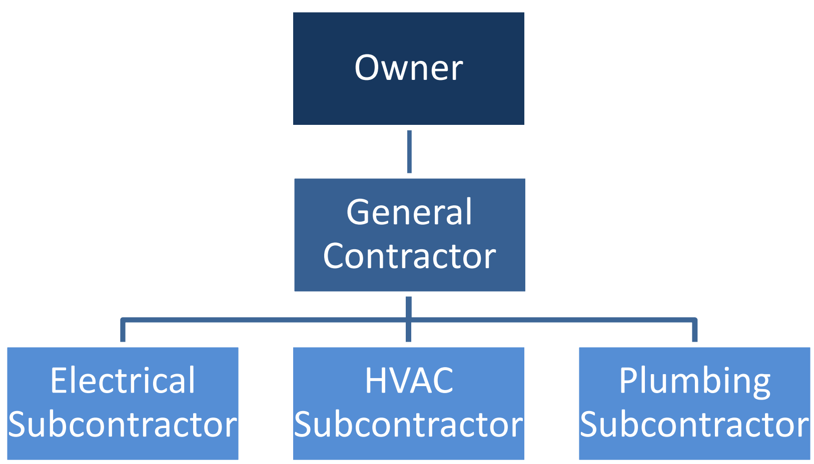


Figure 5.2: Single Prime Flow Chart



Advantages and Disadvantages of the Multiple Prime Delivery Method

The multiple prime delivery method has its advantages and disadvantages as does any other delivery system. Every project is unique and has many different things that can affect which project delivery system will work best and be most efficient for that particular project.

The multiple prime delivery method sometimes works well for projects where cost is the driver because the competitive bid theoretically ensures that the owner will get the lowest price for a given scope of work. In addition, multiple prime can eliminate double mark-ups on scopes of work. For instance, instead of a general contractor marking up the price that their mechanical subcontractor bid to them the owner should technically just get marked up once by the mechanical prime. However, projects that use the multiple prime delivery method should make sure that their construction documents are very complete.

Often times with multiple prime delivery contractors will be at or below the cost of work with the mindset that they will make up their profit through change orders. Incomplete documents or documents that lack the appropriate amount of detail leave the owner vulnerable to multiple change orders throughout the project. Change orders are very expensive because at that point in the project the owner doesn't have the luxury of deciding what contractor to go with. Therefore, the owner is at the mercy of the subcontractor's price since typically the change order needs to be completed, usually quickly, and there would be no time to bid out the work to other contractors.

Lastly, multiple prime delivery isn't a good choice for inexperienced owners, unless they have the funds to hire a representative or agent, due to the fact that they will hold multiple contracts which significantly increases organization and coordination.

The advantages of the multiple prime delivery method include:

- Potential for lowest cost of work
- Aids in organization for a large project where the scope of work could be broken down into smaller packages
- Potential for fast tracking

The disadvantages of the multiple prime delivery method include:

- Increased need for coordination and communication
- Excessive number of managers on site
- Increased paperwork and organization load on part of owner
- Duplicated costs (i.e. site supervisors for each prime)
- Increased litigation potential against owner
- Greater potential for change orders due to bidding at loss

Case Study #1: SCI Benner Twp. / Department of General Services Projects

The Pennsylvania Department of General Services (DGS) oversees the procurement of good and services, manages non-highway capital, and has a few other miscellaneous responsibilities such as managing the state vehicle fleet and the Capitol Police force. DGS sent out RFP's for the construction of a new facility at the State Correctional Institute at Benner Twp. The project was to be a multiple prime delivery method as is typical for government projects due to the Pennsylvania Separations Act of 1913 which is discussed above. However, the bids came in well over total budget for the project of $181,550,000.00. The state then reviewed the project and sent out another RFP, however, this time the project was to be a design-build project. The DGS was able to specify a design-build contract due to Section 19 of the DGS procurement policy.

Section 19 states that:

"The department of General Services shall use the competitive sealed proposal method of source selection to enter into a design/build contract for the projects which are authorized in section 3 (4) (i), (iii), (vi), (viii), (ix), (x) (B), (xi) (B), (xii) (B), (xiii), (xiv), (xvi) and (xix) and section 11 (1). Notwithstanding the provisions of 62 Pa.C.S. S 322(6) (relating to specific construction powers, duties and procedures), the Department of General Services shall comply with the provisions of the act of May 1, 1913 (P.L.155, No.104), referred to as the Separations Act, by entering into a design/build contract which requires that the design/build contractor comply with the requirements of the Separations Act.

In other words, DGS can opt to specify the project as design-build by placing the responsibilities of the Separations Act on the Design-Build contractor. Part of this requirement is that the design-build contractor call out who their electrical, mechanical, and plumbing contractors will be for the project during the time at which they place their bid. This policy allows the state to comply with the intent of the Separations act while reducing the following:

- Points of contact to on contractors
- Potential legislation against the state
- Amount of paperwork and management on behalf of the state
- Time required for project coordination

After interviewing the Assistant Chief Counsel for the Department of General Services, Edmond C. Olivieri, it became clear that this ability to perform DGS projects as design-build as oppose to multiple prime is solely at the discretion of DGS and there is nothing that a bidding contractor can directly do to influence the decision. However, contractors can indirectly influence the department's decision to invoke Section 19 if the bids that come in do not align with the department's expectations as was the case with SCI at Benner Twp.

Department of Education Projects

The Mandate Waiver Program by the Department of Education (DOE), which was part of the Education Empowerment Act (EEA), was passed in 2000. The program stated that the board of any school district "may apply for a waiver to any provision of the Public School Code of 1949, the Regulations of the State Board of Education or the Standards of the Secretary of Education if the waiver will enable the applicant to improve its instruction program or operate in a more effective, efficient or economical manner." This allowed school districts to apply for a waiver from the Separations Act with the argument that the waiver would allow the school districts to operate (build) in a more efficient and economical manner. Indeed, the separations act was the most widely applied for exemption under the waiver program. By 2007, 65 school districts had applied for a waiver from the Separations Act.

In 2003 and 2004 a couple of mechanical contractors filed law suits against school districts that had applied for and planned on using the waivers. They're argument was that the Education Empowerment Act only provided an exemption from the School Code since the PDE has no authority to exempt a district from general state law which also contained the separations act. Indeed, the commonwealth courts ruled that the PDE could only grant waivers from the school code and therefore all school districts must still abide by the separations act which was also contained in the general state law. Shortly thereafter, many of the school districts that had been granted waivers were no longer allowed to use them. However, there were a few projects that were grandfathered in due to the projects being too far along in the project to switch delivery methods. The legislation was challenged in court on multiple occasions. After multiple rulings, lawsuits, and appeals, the state Supreme Court upheld that the Secretary of Education had the authority to waive school districts from the requirements of the Separations Act as provided the Mandate Waiver Program in the EEA.

According to a study by the Pennsylvania Economy League of Southwestern Pennsylvania, school districts that did not apply for the waiver and utilized the multiple prime delivery method reported:

- At least a 3% cost overrun associated with every multiple prime project
- Project management issues
- Elevated stress levels during the project

Projects that utilized a single prime delivery system reported:

- Improved communication
- Significant reduction in required management time
- Improved chances of meeting of beating deadlines
- Improved chances of finishing at or under budget
- Fewer cost overruns
- Significant decrease in resulting litigation
- Improved quality of work.

Despite the obvious benefits of single prime projects over multiple prime projects, an interview with the assistant counsel for the DOE, Robert M. Tomaine, confirmed that the EEA, which includes the waiver program, expired in 2010. This means that school districts can no longer apply for waivers. Mr. Tomaine also said that to his knowledge there are no plans to renew the legislation as well as no new pieces of legislation that would provide the same ability to waive the separations act that are being worked on currently.

Boroughs, Townships, Counties, Second-Class Townships, Third Class Cities

As stated above, the Pennsylvania Separations Act of 1913 has been repealed for boroughs, townships, counties, second-class townships, and third class cities. These classifications of towns do not have to apply with the Separations Act even if the cost of the project will exceed $4000. The exemption for these classifications was probably made to the often cash strapped and vulnerable towns under these classifications in order to allow the towns to reduce the amount of management, paperwork, risk, and legislation that could accompany each project. This will ultimately allow these towns with resources that are much more limited than those of bigger cities and state agencies to improve and grow at a greater rate than what would be possible under the Separations Act.

Effect of Multiple Prime on Landis Run Intermediate

Through discussions with the general contractor's project manager as well as through research, it has been determined that a single prime delivery method could have improved the efficiency, cost, and schedule of the project as well as reduced required time, management, and coordination on behalf of the owner. Although LRI is a relatively successful project since it is currently under budget and on schedule there is always room for improvement. Furthermore, there have been some significant coordination issues and additional costs that could have potentially been avoided under a single prime delivery method. A study by the Pennsylvania Economy League of Southwestern Pennsylvania compiled surveys that were sent to multiple school districts which performed past projects using multiple prime as well as projects that had been granted a Waiver from the Separations Act and utilized single prime. A vast majority of the districts cited improved communication, efficiency, savings, schedule performance, and quality while utilizing single prime as oppose to multiple prime. These benefits could have been reaped on LRI as well to avoid coordination errors, decrease costs, increase quality, and improve the project as a whole.

Conclusions/Recommendations

Analysis 1

It has been shown that the site on LRI could accommodate enough geothermal heat pumps to supply the entire building load. This would come at an increased initial cost to the owner; however, it would ultimately save the owner money in the long run due to the system's high efficiency when compared with the existing system. Furthermore, the owner should be able to absorb the initial 3.4% cost increase for the project since it was bid under budget. In addition, the geothermal heat pump system would serve to significantly increase the sustainability of the building as well as improve the LEED rating of the building from Silver to Gold. The installation of the system would not cause an increase in the project schedule nor require a change in the general construction strategy.

It is concluded that LRI should have utilized a geothermal heat pump system in order to decrease life time utility costs and increase sustainability of the building.

Analysis 2

Utilizing modular construction, which is purely a method of construction and does not change or limit the design in any way, could reduce the cost of construction by $3.72 Million or 14.1%. In addition, it is estimated that it could accelerate the completion of the classroom wings by nearly a year. This would almost certainly allow a more concentrated and quicker construction effort for the two remaining areas resulting in a substantially earlier finish for the entire building. Furthermore, these benefits come at no cost to the quality, safety, or sustainability of the project.

The modular classroom design used on LRI could be utilized for other schools across the state and save those school districts money and time. In addition, it would assure that children in every school district have access to a quality learning environment. Simple changes to the modules can be made to adjust for class size, aesthetics, and technology utilization.

It is concluded that LRI should have had its classrooms constructed modularly in order to save time and money on the project. In addition, it is recommended that the state utilize standard classroom plans for schools due to their similar program requirements in order to save time and money as well as standardize the quality of the state's schools.

Analysis 3

It has been shown that when compared with the underground rough-in method, overhead rough-in could have:

- Been completed 35 working days sooner
- Resulted in earlier dry-in dates by an average of 23 days
- Saved either the electrical prime, owner, or both approximately $50,000

In terms of cost and schedule on LRI the difference between the two methods were significant. Saving 35 working days also saves 35 days of general conditions for both the electrical prime and the general prime. It also results in an earlier move in date for the owner. In addition, although $50,000 is small when compared with the overall cost of the project it is still a significant amount of money that the owner would certainly like to have back or to use in case of unforeseen costs associated with the project down the road.

The only differences that UG rough-in provides is serving to decrease congestion during the interior phase of the building by spreading of the electrical prime's work throughout the whole project as oppose to just one phase. However, there is no evidence as of yet nor are there any expected issues with over congestion or coordination during the interior phase of work in the building. Therefore, it is extremely reasonable to assume that the electrical prime could have performed the building entirely using OH rough-in without making the project over complex to the point of added cost or resources.

It is concluded that 100% OH rough-in should have been performed to save time and money since the benefits of UG rough-in are estimated to be insignificant.

Analysis 4

Contractors may be able to utilize a Design-Build delivery method on a DGS project. However, there is nothing that the contractor can do to influence that decision. The decision will be made by the DGS prior to bid. The DGS, as was the case with SCI at Benner Twp., might revise the RFP from one method to another if the initial bids received were not coming in at the expected costs or time frame.

For K-12 projects, or other projects managed by school districts or the DOE, there is currently no way to utilize any other method than multiple prime. There was a method to achieve such a result under the Mandate Waiver Program but that act expired in 2010. There are no plans to renew the act or pass any similar legislation.

Boroughs, Townships, Counties, Second-Class Townships, and Third Class Cities are exempt from the Pennsylvania Separations Act no matter what the project cost.

In conclusion, there are no loopholes or other means for a contractor to achieve permission to utilize an alternative delivery system on a state funded project unless that project is for an owner whose classification is a borough, township, county, second-class township, or third class city.

Acoustical Breadth

The fact that the drywall in the modular assembly performs less noise reduction does not mean that it performs inadequate noise reduction. ASHRAE recommends background noise levels for classrooms to be between 30-35 dB. To put this in perspective, 60 dB is the sound level one experiences when they're near highway traffic. The noise levels that these assemblies would actually experience cannot be calculated since the level of noise from the source room is not known. However, the noise level that would have to be present in the source room for the noise level in the receiving room to be too loud would be 79 dB (44 dB + 35 dB), at its loudest at the 2k Hz octave. This level of sound would likely never be reached in a classroom.

Mechanical Breadth

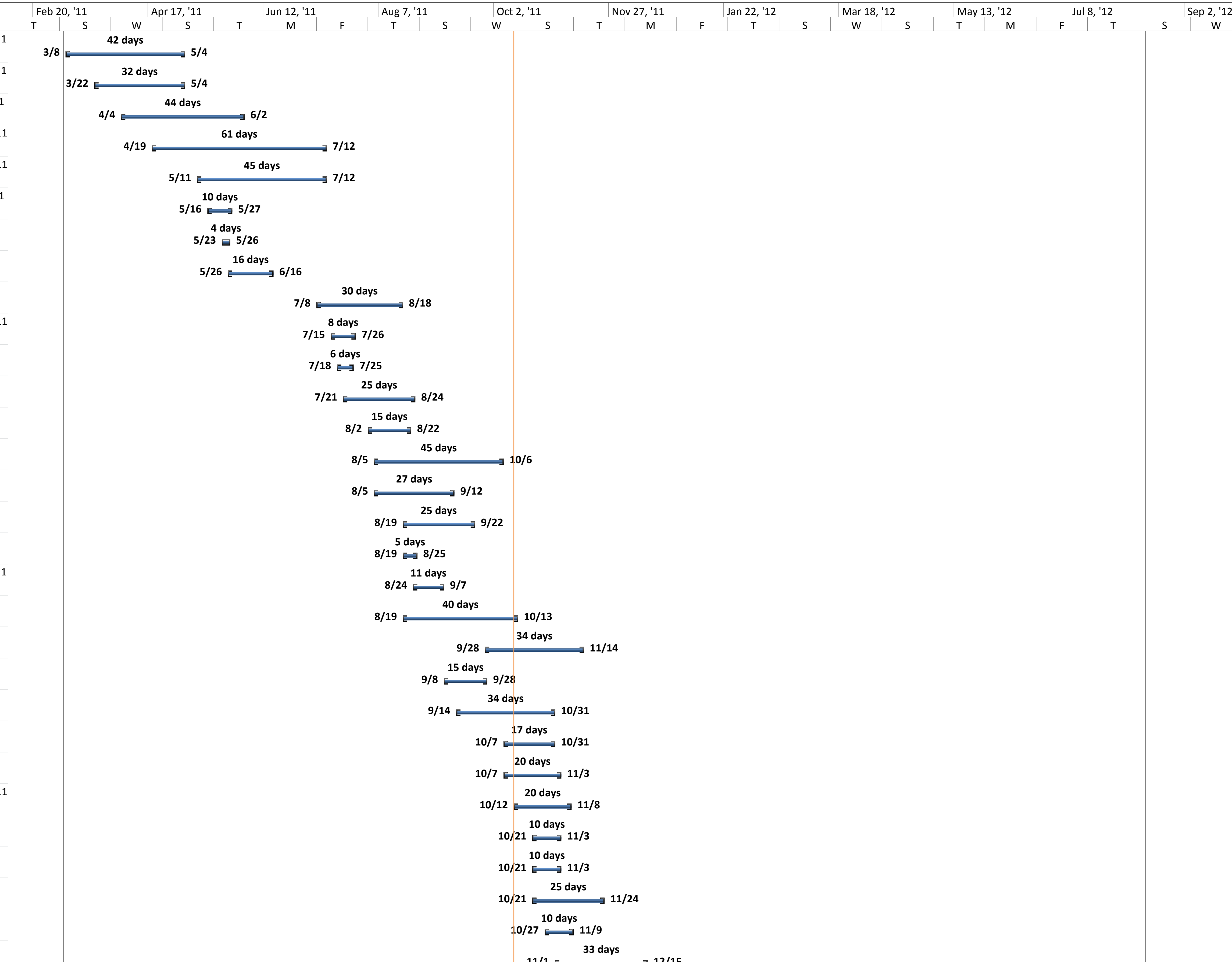
Not only can the existing mechanical system be reduced with the addition of a geothermal heat pump system but rather it can be completely eliminated resulting in lower energy costs over the lifetime of the building as well as an increase in the building's sustainability.

Appendix A

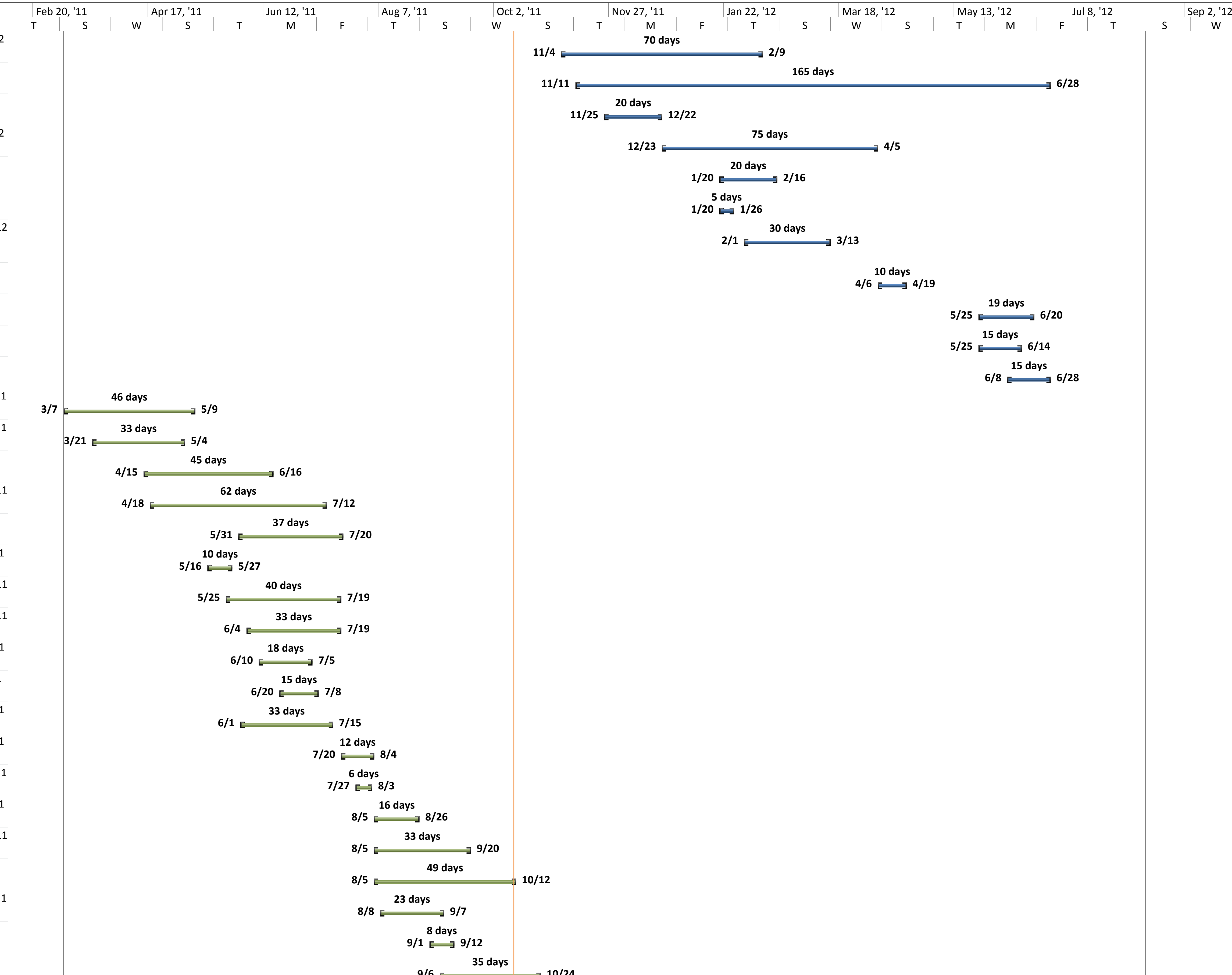
Detailed Project Schedule

Landis Run Intermediate School | Detailed Project Schedule

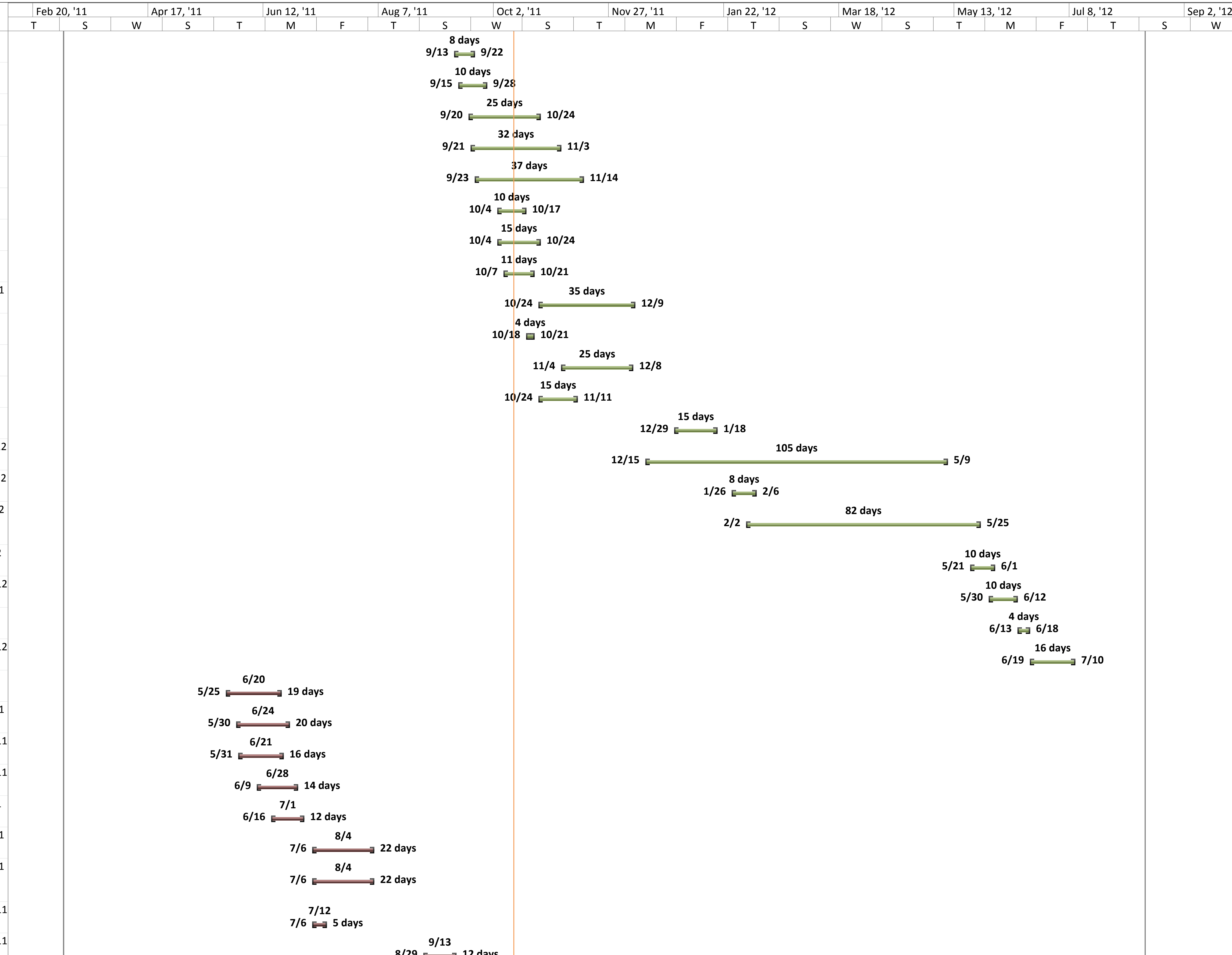
ID	Area	Activity	Duration	Start	Finish
1	Area A	Layout, Excavate, & Place Footing	42 days	Tue 3/8/11	Wed 5/4/11
2	Area A	Masonry Wall to SOG Elevation	32 days	Tue 3/22/11	Wed 5/4/11
3	Area A	Plumbing & Electrical Rough-In	44 days	Mon 4/4/11	Thu 6/2/11
4	Area A	Masonry Walls to Bearing Height	61 days	Tue 4/19/11	Tue 7/12/11
5	Area A	Elec, Low Voltage. & Plumbing In Wall Rough-In	45 days	Wed 5/11/11	Tue 7/12/11
6	Area A	Install Floor Joists & Deck	10 days	Mon 5/16/11	Fri 5/27/11
7	Area A	FRP Slab Except Caf. & Gym	4 days	Mon 5/23/11	Thu 5/26/11
8	Area A	Install Door Frames	16 days	Thu 5/26/11	Thu 6/16/11
9	Area A	Install Roof Joists & Deck	30 days	Fri 7/8/11	Thu 8/18/11
10	Area A	Spray Foam Insulation	8 days	Fri 7/15/11	Tue 7/26/11
11	Area A	FRP Caf. & Gym SOG	6 days	Mon 7/18/11	Mon 7/25/11
12	Area A	HVAC, Plumb., Elec. Gym Overhead Rough-In	25 days	Thu 7/21/11	Wed 8/24/11
13	Area A	Metal Stud Wall Framing	15 days	Tue 8/2/11	Mon 8/22/11
14	Area A	Roofing & Roof Drains	45 days	Fri 8/5/11	Thu 10/6/11
15	Area A	HVAC Ducts, Pipes, Hangers, Mains, Branches & Test	27 days	Fri 8/5/11	Mon 9/12/11
16	Area A	Sprinkler RI & Branch Piping	25 days	Fri 8/19/11	Thu 9/22/11
17	Area A	Gas Piping	5 days	Fri 8/19/11	Thu 8/25/11
18	Area A	Brick Veneer	11 days	Wed 8/24/11	Wed 9/7/11
19	Area A	AHU Installation	40 days	Fri 8/19/11	Thu 10/13/11
20	Area A	AHU Tie-In	34 days	Wed 9/28/11	Mon 11/14/11
21	Area A	Install Windows/Curtainwall	15 days	Thu 9/8/11	Wed 9/28/11
22	Area A	Elec. & Dom. Water RI and Branch Piping	34 days	Wed 9/14/11	Mon 10/31/11
23	Area A	Install Mech. Equipment & Piping	17 days	Fri 10/7/11	Mon 10/31/11
24	Area A	Apply Block Filler & Paint	20 days	Fri 10/7/11	Thu 11/3/11
25	Area A	Insulate Ductwork & Piping	20 days	Wed 10/12/11	Tue 11/8/11
26	Area A	Install Kitchen Equipment	10 days	Fri 10/21/11	Thu 11/3/11
27	Area A	Install Cabe Tray	10 days	Fri 10/21/11	Thu 11/3/11
28	Area A	Install & Finish Drywall, Bulkheads, Soffits & Panels	25 days	Fri 10/21/11	Thu 11/24/11
29	Area A	Equipment Tie-Ins, Ductwork & Piping	10 days	Thu 10/27/11	Wed 11/9/11
30	Area A	Elec., HVAC, Fire Alarm & Security Wiring	33 days	Tue 11/1/11	Thu 12/15/11



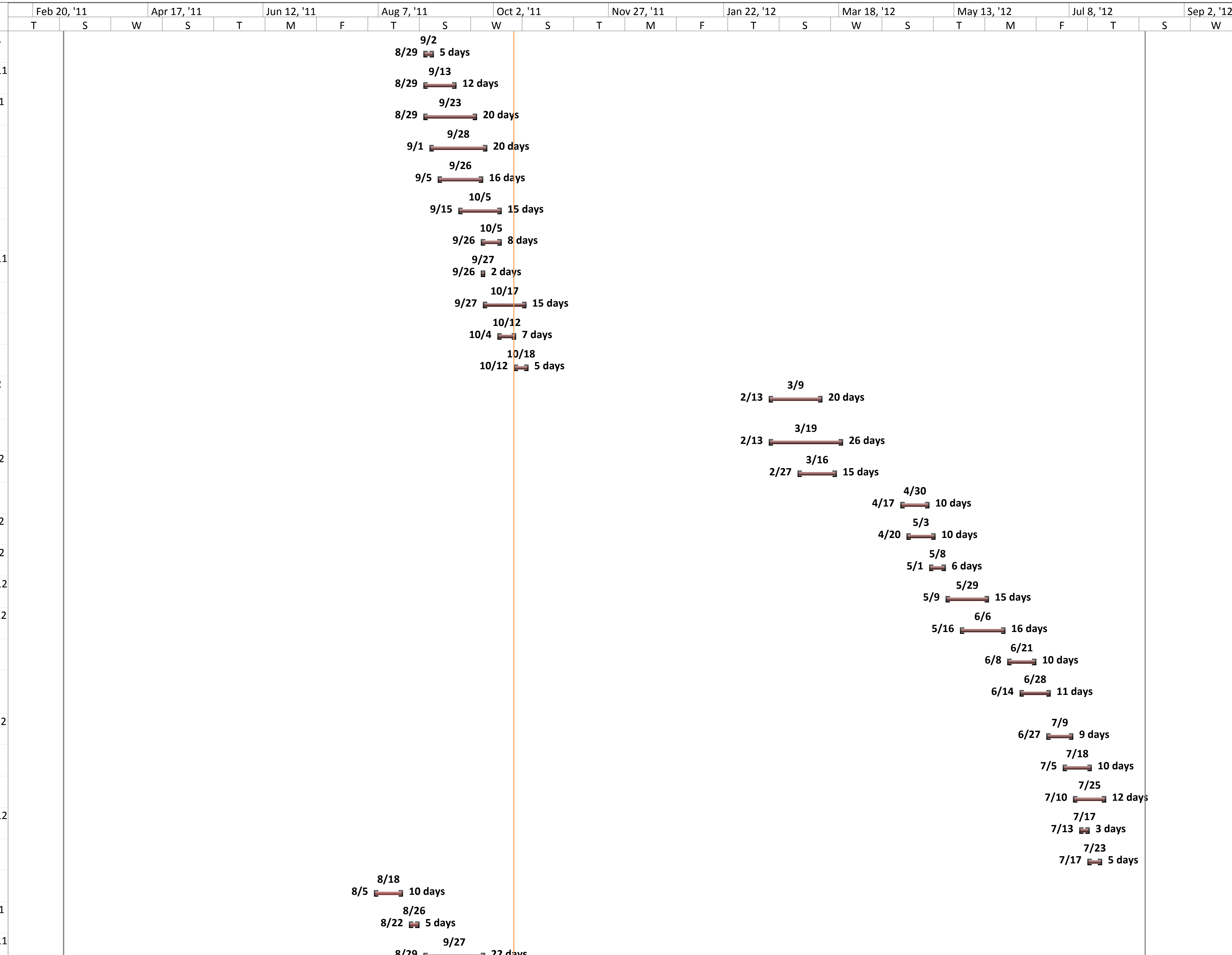
ID	Area	Activity	Duration	Start	Finish
31	Area A	Install Light Fixtures & Devices	70 days	Fri 11/4/11	Thu 2/9/12
32	Area A	Gym Specialties & Equipment	165 days	Fri 11/11/11	Thu 6/28/12
33	Area A	Flooring	20 days	Fri 11/25/11	Thu 12/22/11
34	Area A	Ceiling Grid & Tile	75 days	Fri 12/23/11	Thu 4/5/12
35	Area A	Install Sprinkler Drop Heads	20 days	Fri 1/20/12	Thu 2/16/12
36	Area A	Lockers & Hallway Specialties	5 days	Fri 1/20/12	Thu 1/26/12
37	Area A	Fire Alarm, Security, Data, Sound, Clock, Classroom Media Finishes	30 days	Wed 2/1/12	Tue 3/13/12
38	Area A	Casework	10 days	Fri 4/6/12	Thu 4/19/12
39	Area A	Plumbing Fixtures & Toilet Specialties	19 days	Fri 5/25/12	Wed 6/20/12
40	Area A	Millwork	15 days	Fri 5/25/12	Thu 6/14/12
41	Area A	Install Doors & Accessories	15 days	Fri 6/8/12	Thu 6/28/12
42	Area B	Layout, Excavate, & Place Footing	46 days	Mon 3/7/11	Mon 5/9/11
43	Area B	Masonry Wall to SOG Elevation	33 days	Mon 3/21/11	Wed 5/4/11
44	Area B	Plumbing & Electrical Rough-In	45 days	Fri 4/15/11	Thu 6/16/11
45	Area B	Masonry Walls to Bearing Height	62 days	Mon 4/18/11	Tue 7/12/11
46	Area B	Elec, Low Voltage. & Plumbing In Wall Rough-In	37 days	Tue 5/31/11	Wed 7/20/11
47	Area B	Install Floor Joists & Deck	10 days	Mon 5/16/11	Fri 5/27/11
48	Area B	FRP Slab	40 days	Wed 5/25/11	Tue 7/19/11
49	Area B	Install Door Frames	33 days	Sat 6/4/11	Tue 7/19/11
50	Area B	Install Composite Sheet Waterproofing	18 days	Fri 6/10/11	Tue 7/5/11
51	Area B	Backfill Basement Walls	15 days	Mon 6/20/11	Fri 7/8/11
52	Area B	Complete All UG MEP Rough In	33 days	Wed 6/1/11	Fri 7/15/11
53	Area B	Install Roof Joists & Deck	12 days	Wed 7/20/11	Thu 8/4/11
54	Area B	Spray Foam Insulation	6 days	Wed 7/27/11	Wed 8/3/11
55	Area B	Install Plumbing Equipment	16 days	Fri 8/5/11	Fri 8/26/11
56	Area B	Install Elec. Panels, Transformers, and Conduit	33 days	Fri 8/5/11	Tue 9/20/11
57	Area B	Metal Stud Framing & Drywall	49 days	Fri 8/5/11	Wed 10/12/11
58	Area B	Roofing & Roof Drains	23 days	Mon 8/8/11	Wed 9/7/11
59	Area B	Brick Veneer	8 days	Thu 9/1/11	Mon 9/12/11
60	Area B	HVAC Ducts, Pipes, Hangers, Mains, Branches & Test	35 days	Tue 9/6/11	Mon 10/24/11



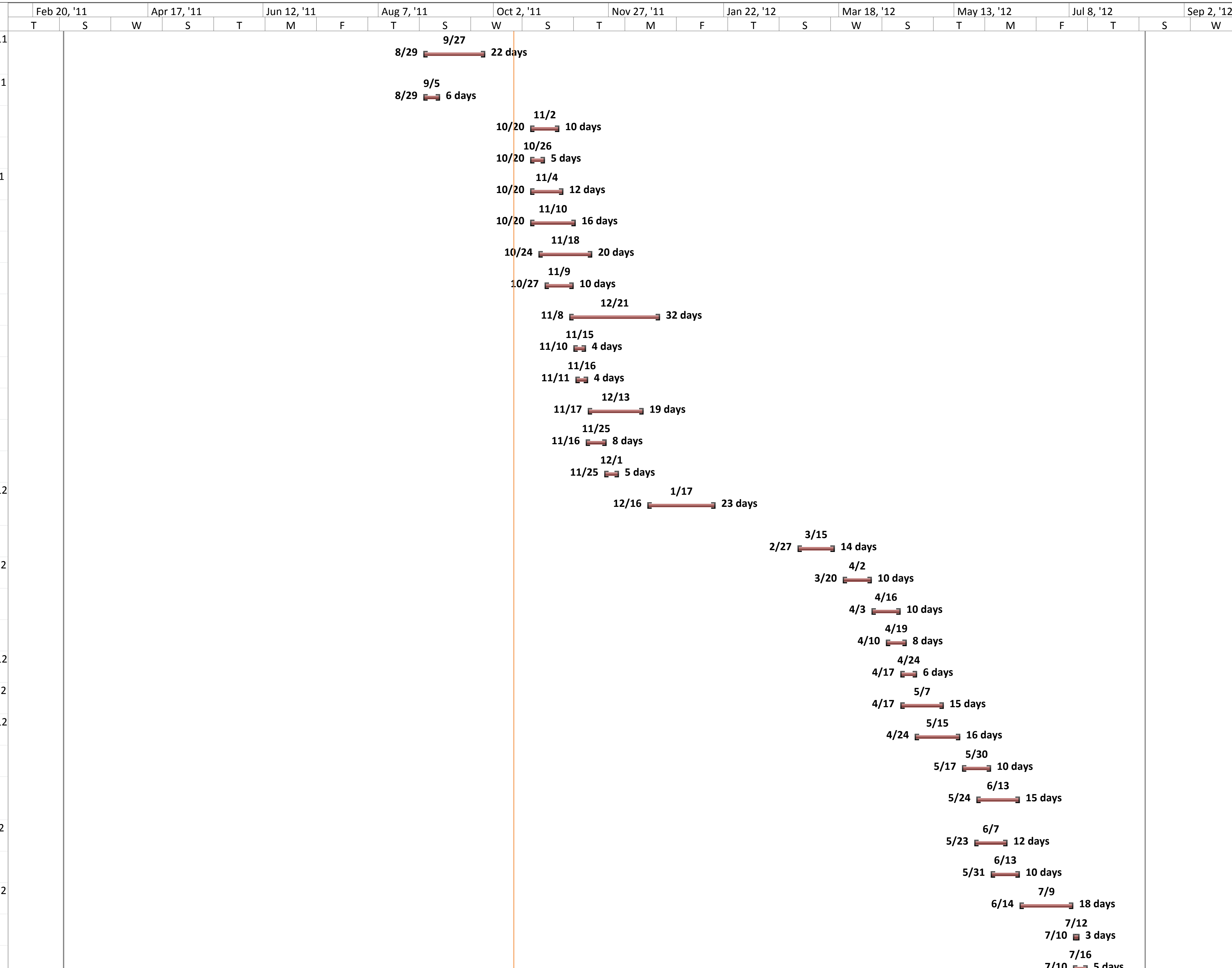
ID	Area	Activity	Duration	Start	Finish
61	Area B	Install Windows/Curtainwall	8 days	Tue 9/13/11	Thu 9/22/11
62	Area B	Apply Block Filler & Paint	10 days	Thu 9/15/11	Wed 9/28/11
63	Area B	Dom. Water RI and Branch Piping	25 days	Tue 9/20/11	Mon 10/24/11
64	Area B	Terminate Panels, Transformers, and Primary.	32 days	Wed 9/21/11	Thu 11/3/11
65	Area B	Insulate Ductwork & Piping	37 days	Fri 9/23/11	Mon 11/14/11
66	Area B	Sprinkler RI & Branch Piping	10 days	Tue 10/4/11	Mon 10/17/11
67	Area B	Gas Piping	15 days	Tue 10/4/11	Mon 10/24/11
68	Area B	AHU Installation	11 days	Fri 10/7/11	Fri 10/21/11
69	Area B	AHU Tie-In	35 days	Mon 10/24/11	Fri 12/9/11
70	Area B	Install Cable Tray	4 days	Tue 10/18/11	Fri 10/21/11
71	Area B	Install Mech. Equipment & Piping	25 days	Fri 11/4/11	Thu 12/8/11
72	Area B	Elec., HVAC, Fire Alarm & Security Wiring	15 days	Mon 10/24/11	Fri 11/11/11
73	Area B	Install Light Fixtures & Devices	15 days	Thu 12/29/11	Wed 1/18/12
74	Area B	Ceiling Grid & Tile	105 days	Thu 12/15/11	Wed 5/9/12
75	Area B	Install Sprinkler Drop Heads	8 days	Thu 1/26/12	Mon 2/6/12
76	Area B	Fire Alarm, Security, Data, Sound, Clock, Classroom Media Finishes	82 days	Thu 2/2/12	Fri 5/25/12
77	Area B	Casework	10 days	Mon 5/21/12	Fri 6/1/12
78	Area B	Flooring	10 days	Wed 5/30/12	Tue 6/12/12
79	Area B	Plumbing Fixtures & Toilet Specialties	4 days	Wed 6/13/12	Mon 6/18/12
80	Area B	Install Doors & Accessories	16 days	Tue 6/19/12	Tue 7/10/12
81	Area C Ground	Layout, Excavate, & Place Footing	19 days	Wed 5/25/11	Mon 6/20/11
82	Area C Ground	Masonry Foundation Walls to SOG	20 days	Mon 5/30/11	Fri 6/24/11
83	Area C Ground	UG MEP Rough-Ins	16 days	Tue 5/31/11	Tue 6/21/11
84	Area C Ground	Prep & Backfill Foundation Walls	14 days	Thu 6/9/11	Tue 6/28/11
85	Area C Ground	FRP SOG	12 days	Thu 6/16/11	Fri 7/1/11
86	Area C Ground	Masonry Bearing Walls to 1st Floor	22 days	Wed 7/6/11	Thu 8/4/11
87	Area C Ground	Plumbing, Electrical, & Low Voltage in Wall Rough-Ins & Chases	22 days	Wed 7/6/11	Thu 8/4/11
88	Area C Ground	Install Door Frames	5 days	Wed 7/6/11	Tue 7/12/11
89	Area C Ground	Apply Block Filler & Paint	12 days	Mon 8/29/11	Tue 9/13/11



ID	Area	Activity	Duration	Start	Finish
90	Area C Ground	Metal Stud Framing & Drywall	5 days	Mon 8/29/11	Fri 9/2/11
91	Area C Ground	Install Stairs to 1st Floor	12 days	Mon 8/29/11	Tue 9/13/11
92	Area C Ground	HVAC Ducts, Pipes, Hangers, Mains, Branches	20 days	Mon 8/29/11	Fri 9/23/11
93	Area C Ground	Overhead Electrical Rough-In	20 days	Thu 9/1/11	Wed 9/28/11
94	Area C Ground	Sprinkler Rough-In and Branch Piping	16 days	Mon 9/5/11	Mon 9/26/11
95	Area C Ground	Dom. Water RI and Branch Piping	15 days	Thu 9/15/11	Wed 10/5/11
96	Area C Ground	Install Mech. Equipment	8 days	Mon 9/26/11	Wed 10/5/11
97	Area C Ground	Chase Duct for AHU's	2 days	Mon 9/26/11	Tue 9/27/11
98	Area C Ground	Install LV Cable Tray & Pull Wire	15 days	Tue 9/27/11	Mon 10/17/11
99	Area C Ground	Equipment Tie-Ins, Ductwork & Piping	7 days	Tue 10/4/11	Wed 10/12/11
100	Area C Ground	Wire HVAC Equipment	5 days	Wed 10/12/11	Tue 10/18/11
101	Area C Ground	Fire Alarm, Security, Data, Sound, Clock, Classroom Media Cabling	20 days	Mon 2/13/12	Fri 3/9/12
102	Area C Ground	Insulate Ductwork & Piping	26 days	Mon 2/13/12	Mon 3/19/12
103	Area C Ground	Install Elevator	15 days	Mon 2/27/12	Fri 3/16/12
104	Area C Ground	Install Ceiling Grid	10 days	Tue 4/17/12	Mon 4/30/12
105	Area C Ground	Install Sprinkler Drop Heads	10 days	Fri 4/20/12	Thu 5/3/12
106	Area C Ground	Install Resinous Flooring	6 days	Tue 5/1/12	Tue 5/8/12
107	Area C Ground	Install Light Fixtures & Devices	15 days	Wed 5/9/12	Tue 5/29/12
108	Area C Ground	Install Duct Drops	16 days	Wed 5/16/12	Wed 6/6/12
109	Area C Ground	Ceiling Tile	10 days	Fri 6/8/12	Thu 6/21/12
110	Area C Ground	Fire Alarm, Security, Data, Sound, Clock, Classroom Media Finishes	11 days	Thu 6/14/12	Thu 6/28/12
111	Area C Ground	Casework & Lockers	9 days	Wed 6/27/12	Mon 7/9/12
112	Area C Ground	Flooring	10 days	Thu 7/5/12	Wed 7/18/12
113	Area C Ground	Plumbing Fixtures & Toilet Specialties	12 days	Tue 7/10/12	Wed 7/25/12
114	Area C Ground	Doors & Hardware	3 days	Fri 7/13/12	Tue 7/17/12
115	Area C Ground	Classroom Specialties	5 days	Tue 7/17/12	Mon 7/23/12
116	Area C 1st Floor	Install Joists & Deck	10 days	Fri 8/5/11	Thu 8/18/11
117	Area C 1st Floor	Prep & Place Slab on Deck	5 days	Mon 8/22/11	Fri 8/26/11
118	Area C 1st Floor	Masonry Bearing Walls to 2nd Floor	22 days	Mon 8/29/11	Tue 9/27/11

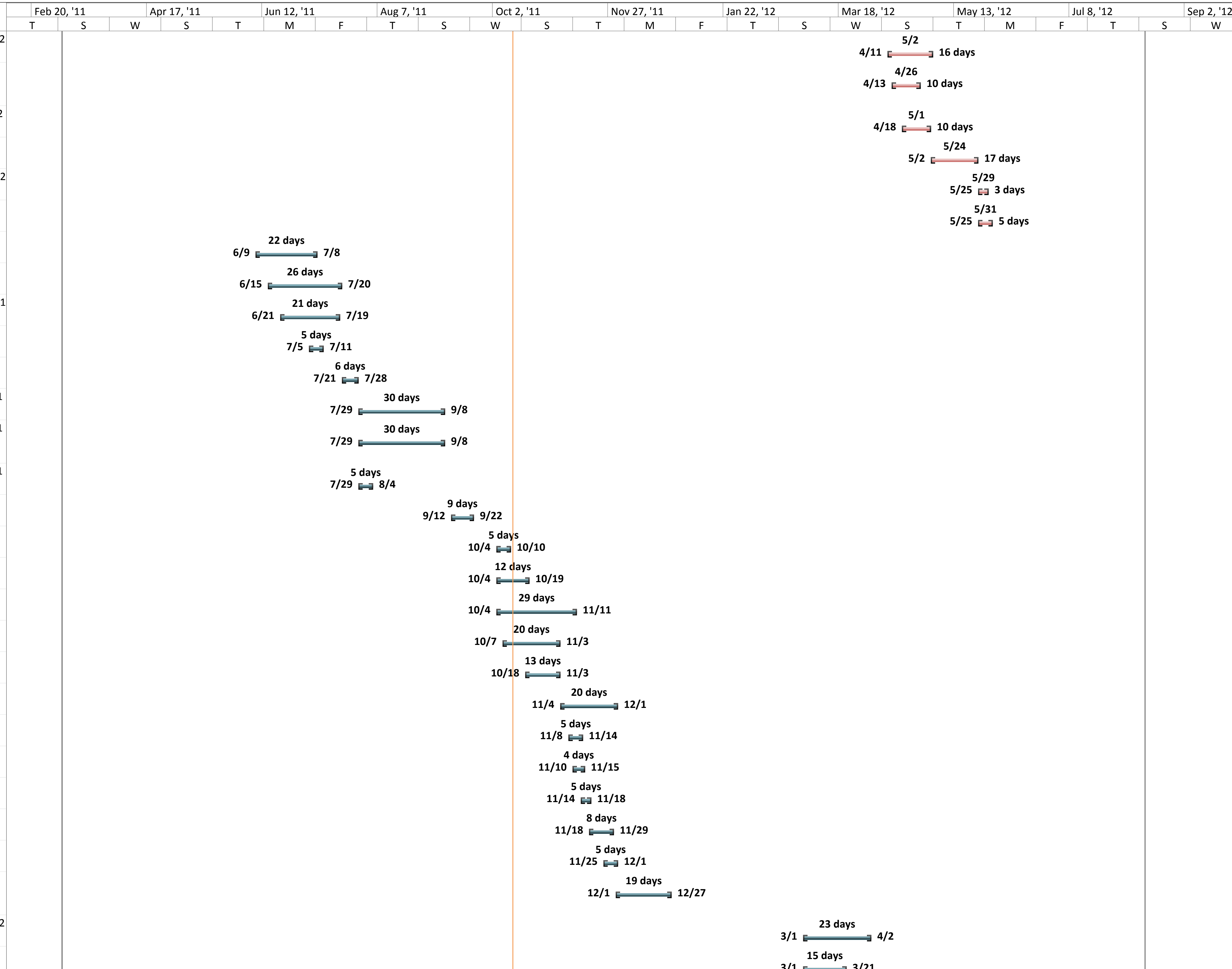


ID	Area	Activity	Duration	Start	Finish
119	Area C 1st Floor	Plumbing, Electrical, & Low Voltage in Wall Rough-Ins & Chases	22 days	Mon 8/29/11	Tue 9/27/11
120	Area C 1st Floor	Install Door Frames	6 days	Mon 8/29/11	Mon 9/5/11
121	Area C 1st Floor	Apply Block Filler & Paint	10 days	Thu 10/20/11	Wed 11/2/11
122	Area C 1st Floor	Metal Stud Framing & Drywall	5 days	Thu 10/20/11	Wed 10/26/11
123	Area C 1st Floor	Install Stairs to 2nd Floor	12 days	Thu 10/20/11	Fri 11/4/11
124	Area C 1st Floor	HVAC Ducts, Pipes, Hangers, Mains, Branches	16 days	Thu 10/20/11	Thu 11/10/11
125	Area C 1st Floor	Overhead Electrical Rough-In	20 days	Mon 10/24/11	Fri 11/18/11
126	Area C 1st Floor	Sprinkler Rough-In and Branch Piping	10 days	Thu 10/27/11	Wed 11/9/11
127	Area C 1st Floor	Dom. Water RI and Branch Piping	32 days	Tue 11/8/11	Wed 12/21/11
128	Area C 1st Floor	Install Mech. Equipment	4 days	Thu 11/10/11	Tue 11/15/11
129	Area C 1st Floor	Chase Duct for AHU's	4 days	Fri 11/11/11	Wed 11/16/11
130	Area C 1st Floor	Install LV Cable Tray & Pull Wire	19 days	Thu 11/17/11	Tue 12/13/11
131	Area C 1st Floor	Equipment Tie-Ins, Ductwork & Piping	8 days	Wed 11/16/11	Fri 11/25/11
132	Area C 1st Floor	Wire HVAC Equipment	5 days	Fri 11/25/11	Thu 12/1/11
133	Area C 1st Floor	Fire Alarm, Security, Data, Sound, Clock, Classroom Media Cabling	23 days	Fri 12/16/11	Tue 1/17/12
134	Area C 1st Floor	Insulate Ductwork & Piping	14 days	Mon 2/27/12	Thu 3/15/12
135	Area C 1st Floor	Install Drywall	10 days	Tue 3/20/12	Mon 4/2/12
136	Area C 1st Floor	Install Ceiling Grid	10 days	Tue 4/3/12	Mon 4/16/12
137	Area C 1st Floor	Install Sprinkler Drop Heads	8 days	Tue 4/10/12	Thu 4/19/12
138	Area C 1st Floor	Install Resinous Flooring	6 days	Tue 4/17/12	Tue 4/24/12
139	Area C 1st Floor	Install Light Fixtures & Devices	15 days	Tue 4/17/12	Mon 5/7/12
140	Area C 1st Floor	Install Duct Drops	16 days	Tue 4/24/12	Tue 5/15/12
141	Area C 1st Floor	Ceiling Tile	10 days	Thu 5/17/12	Wed 5/30/12
142	Area C 1st Floor	Fire Alarm, Security, Data, Sound, Clock, Classroom Media Finishes	15 days	Thu 5/24/12	Wed 6/13/12
143	Area C 1st Floor	Casework & Lockers	12 days	Wed 5/23/12	Thu 6/7/12
144	Area C 1st Floor	Flooring	10 days	Thu 5/31/12	Wed 6/13/12
145	Area C 1st Floor	Plumbing Fixtures & Toilet Specialties	18 days	Thu 6/14/12	Mon 7/9/12
146	Area C 1st Floor	Doors & Hardware	3 days	Tue 7/10/12	Thu 7/12/12
147	Area C 1st Floor	Classroom Specialties	5 days	Tue 7/10/12	Mon 7/16/12



ID	Area	Activity	Duration	Start	Finish
148	Area C 2nd Floor	Install Joists & Deck	10 days	Thu 9/29/11	Wed 10/12/11
149	Area C 2nd Floor	Prep & Place Slab on Deck	5 days	Thu 10/13/11	Wed 10/19/11
150	Area C 2nd Floor	Masonry Bearing Walls to Roof	25 days	Mon 11/7/11	Fri 12/9/11
151	Area C 2nd Floor	Plumbing, Electrical, & Low Voltage in Wall Rough-Ins & Chases	25 days	Mon 11/7/11	Fri 12/9/11
152	Area C 2nd Floor	Install Door Frames	5 days	Mon 11/7/11	Fri 11/11/11
153	Area C 2nd Floor	Install Roof Joists & Roof Deck	10 days	Tue 12/13/11	Mon 12/26/11
154	Area C 2nd Floor	Spray Foam Insulation Ground to Roof	15 days	Tue 12/27/11	Mon 1/16/12
155	Area C 2nd Floor	HVAC Ducts, Pipes, Hangers, Mains, Branches	26 days	Tue 12/27/11	Tue 1/31/12
156	Area C 2nd Floor	Roofing & Roof Drains	33 days	Wed 12/28/11	Fri 2/10/12
157	Area C 2nd Floor	Brick Veneer Ground to Roof	20 days	Wed 1/4/12	Tue 1/31/12
158	Area C 2nd Floor	Sprinkler Rough-In and Branch Piping	9 days	Tue 1/3/12	Fri 1/13/12
159	Area C 2nd Floor	Overhead Electrical Rough-In	15 days	Thu 1/5/12	Wed 1/25/12
160	Area C 2nd Floor	Dom. Water RI and Branch Piping	34 days	Thu 1/5/12	Tue 2/21/12
161	Area C 2nd Floor	Install Windows/Curtainwall Ground to Roof	20 days	Wed 1/18/12	Tue 2/14/12
162	Area C 2nd Floor	Install LV Cable Tray & Pull Wire	10 days	Thu 1/26/12	Wed 2/8/12
163	Area C 2nd Floor	Insulate Ductwork & Piping	21 days	Wed 2/8/12	Wed 3/7/12
164	Area C 2nd Floor	Fire Alarm, Security, Data, Sound, Clock, Classroom Media Cabling	15 days	Thu 2/9/12	Wed 2/29/12
165	Area C 2nd Floor	Install Mech. Equipment	4 days	Mon 2/13/12	Thu 2/16/12
166	Area C 2nd Floor	Set Roof Top Units & Misc. Equip.	4 days	Mon 2/13/12	Thu 2/16/12
167	Area C 2nd Floor	Apply Block Filler & Paint	10 days	Mon 2/13/12	Fri 2/24/12
168	Area C 2nd Floor	Equipment Tie-Ins, Ductwork & Piping	6 days	Thu 2/16/12	Thu 2/23/12
169	Area C 2nd Floor	Install Drywall	10 days	Tue 2/21/12	Mon 3/5/12
170	Area C 2nd Floor	Wire HVAC Equipment	5 days	Fri 2/24/12	Thu 3/1/12
171	Area C 2nd Floor	Install Ceiling Grid	15 days	Thu 3/8/12	Wed 3/28/12
172	Area C 2nd Floor	Install Light Fixtures & Devices	15 days	Thu 3/15/12	Wed 4/4/12
173	Area C 2nd Floor	Install Duct Drops	16 days	Thu 3/15/12	Thu 4/5/12
174	Area C 2nd Floor	Install Sprinkler Drop Heads	7 days	Mon 3/19/12	Tue 3/27/12
175	Area C 2nd Floor	Install Resinous Flooring	6 days	Thu 3/29/12	Thu 4/5/12
176	Area C 2nd Floor	Ceiling Tile	13 days	Fri 4/6/12	Tue 4/24/12

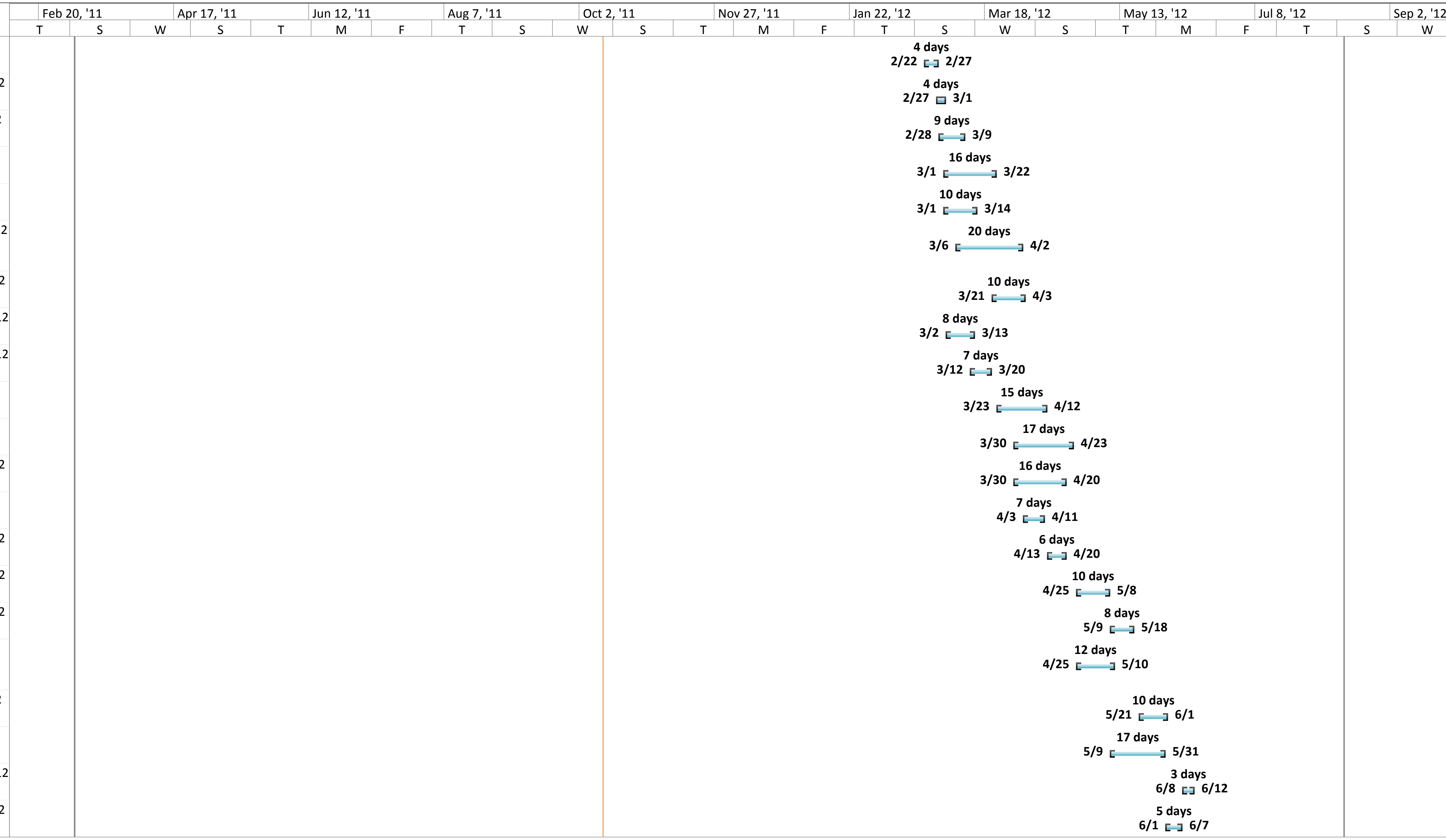
ID	Area	Activity	Duration	Start	Finish
177	Area C 2nd Floor	Casework & Lockers	16 days	Wed 4/11/12	Wed 5/2/12
178	Area C 2nd Floor	Fire Alarm, Security, Data, Sound, Clock, Classroom Media Finishes	10 days	Fri 4/13/12	Thu 4/26/12
179	Area C 2nd Floor	Flooring	10 days	Wed 4/18/12	Tue 5/1/12
180	Area C 2nd Floor	Plumbing Fixtures & Toilet Specialties	17 days	Wed 5/2/12	Thu 5/24/12
181	Area C 2nd Floor	Doors & Hardware	3 days	Fri 5/25/12	Tue 5/29/12
182	Area C 2nd Floor	Classroom Specialties	5 days	Fri 5/25/12	Thu 5/31/12
183	Area D Ground	Layout, Excavate, & Place Footing	22 days	Thu 6/9/11	Fri 7/8/11
184	Area D Ground	Masonry Foundation Walls to SOG	26 days	Wed 6/15/11	Wed 7/20/11
185	Area D Ground	UG MEP Rough-Ins	21 days	Tue 6/21/11	Tue 7/19/11
186	Area D Ground	Prep & Backfill Foundation Walls	5 days	Tue 7/5/11	Mon 7/11/11
187	Area D Ground	FRP SOG	6 days	Thu 7/21/11	Thu 7/28/11
188	Area D Ground	Masonry Bearing Walls to 1st Floor	30 days	Fri 7/29/11	Thu 9/8/11
189	Area D Ground	Plumbing, Electrical, & Low Voltage in Wall Rough-Ins & Chases	30 days	Fri 7/29/11	Thu 9/8/11
190	Area D Ground	Install Door Frames	5 days	Fri 7/29/11	Thu 8/4/11
191	Area D Ground	Apply Block Filler & Paint	9 days	Mon 9/12/11	Thu 9/22/11
192	Area D Ground	Metal Stud Framing & Drywall	5 days	Tue 10/4/11	Mon 10/10/11
193	Area D Ground	Install Stairs to 1st Floor	12 days	Tue 10/4/11	Wed 10/19/11
194	Area D Ground	HVAC Ducts, Pipes, Hangers, Mains, Branches	29 days	Tue 10/4/11	Fri 11/11/11
195	Area D Ground	Overhead Electrical Rough-In	20 days	Fri 10/7/11	Thu 11/3/11
196	Area D Ground	Sprinkler Rough-In and Branch Piping	13 days	Tue 10/18/11	Thu 11/3/11
197	Area D Ground	Dom. Water RI and Branch Piping	20 days	Fri 11/4/11	Thu 12/1/11
198	Area D Ground	Install LV Cable Tray & Pull Wire	5 days	Tue 11/8/11	Mon 11/14/11
199	Area D Ground	Chase Duct for AHU's	4 days	Thu 11/10/11	Tue 11/15/11
200	Area D Ground	Install Mech. Equipment	5 days	Mon 11/14/11	Fri 11/18/11
201	Area D Ground	Equipment Tie-Ins, Ductwork & Piping	8 days	Fri 11/18/11	Tue 11/29/11
202	Area D Ground	Wire HVAC Equipment	5 days	Fri 11/25/11	Thu 12/1/11
203	Area D Ground	Fire Alarm, Security, Data, Sound, Clock, Classroom Media Cabling	19 days	Thu 12/1/11	Tue 12/27/11
204	Area D Ground	Insulate Ductwork & Piping	23 days	Thu 3/1/12	Mon 4/2/12
205	Area D Ground	Install Elevator	15 days	Thu 3/1/12	Wed 3/21/12



ID	Area	Activity	Duration	Start	Finish
206	Area D Ground	Metal Stud Framing & Drywall	10 days	Wed 4/11/12	Tue 4/24/12
207	Area D Ground	Install Ceiling Grid	15 days	Fri 5/4/12	Thu 5/24/12
208	Area D Ground	Install Sprinkler Drop Heads	10 days	Wed 5/16/12	Tue 5/29/12
209	Area D Ground	Install Resinous Flooring	6 days	Fri 5/25/12	Fri 6/1/12
210	Area D Ground	Install Light Fixtures & Devices	15 days	Fri 5/18/12	Thu 6/7/12
211	Area D Ground	Install Duct Drops	18 days	Wed 5/16/12	Fri 6/8/12
212	Area D Ground	Ceiling Tile	10 days	Tue 6/12/12	Mon 6/25/12
213	Area D Ground	Fire Alarm, Security, Data, Sound, Clock, Classroom Media Finishes	14 days	Tue 6/19/12	Fri 7/6/12
214	Area D Ground	Casework & Lockers	10 days	Tue 6/26/12	Mon 7/9/12
215	Area D Ground	Flooring	15 days	Tue 7/10/12	Mon 7/30/12
216	Area D Ground	Plumbing Fixtures & Toilet Specialties	17 days	Fri 7/13/12	Mon 8/6/12
217	Area D Ground	Doors & Hardware	3 days	Tue 8/7/12	Thu 8/9/12
218	Area D Ground	Classroom Specialties	5 days	Tue 8/7/12	Mon 8/13/12
219	Area D 1st Floor	Install Joists & Deck	10 days	Fri 9/9/11	Thu 9/22/11
220	Area D 1st Floor	Prep & Place Slab on Deck	6 days	Mon 9/26/11	Mon 10/3/11
221	Area D 1st Floor	Masonry Bearing Walls to 2nd Floor	25 days	Tue 10/4/11	Mon 11/7/11
222	Area D 1st Floor	Plumbing, Electrical, & Low Voltage in Wall Rough-Ins & Chases	25 days	Tue 10/4/11	Mon 11/7/11
223	Area D 1st Floor	Install Door Frames	5 days	Tue 10/4/11	Mon 10/10/11
224	Area D 1st Floor	Install Stairs to 2nd Floor	12 days	Thu 12/1/11	Fri 12/16/11
225	Area D 1st Floor	HVAC Ducts, Pipes, Hangers, Mains, Branches	35 days	Thu 12/1/11	Wed 1/18/12
226	Area D 1st Floor	Overhead Electrical Rough-In	20 days	Tue 12/6/11	Mon 1/2/12
227	Area D 1st Floor	Sprinkler Rough-In and Branch Piping	13 days	Thu 12/15/11	Mon 1/2/12
228	Area D 1st Floor	Install Mech. Equipment	4 days	Thu 12/22/11	Tue 12/27/11
229	Area D 1st Floor	Equipment Tie-Ins, Ductwork & Piping	28 days	Wed 12/28/11	Fri 2/3/12
230	Area D 1st Floor	Install LV Cable Tray & Pull Wire	24 days	Fri 12/30/11	Wed 2/1/12
231	Area D 1st Floor	Dom. Water RI and Branch Piping	22 days	Tue 1/3/12	Wed 2/1/12
232	Area D 1st Floor	Chase Duct for AHU's	4 days	Thu 1/19/12	Tue 1/24/12
233	Area D 1st Floor	Wire HVAC Equipment	5 days	Mon 1/23/12	Fri 1/27/12
234	Area D 1st Floor	Fire Alarm, Security, Data, Sound, Clock, Classroom Media Cabling	18 days	Thu 2/2/12	Mon 2/27/12

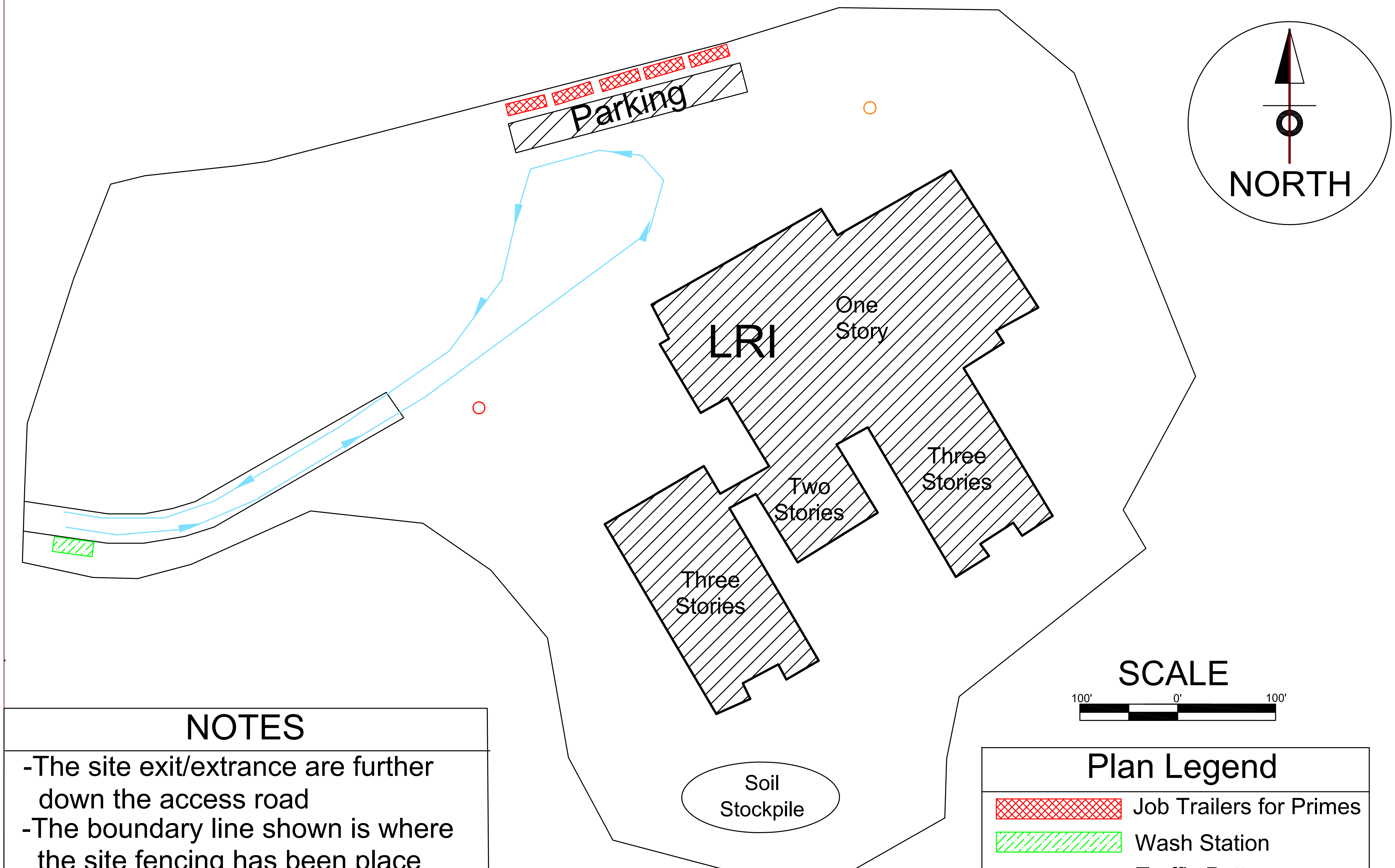
ID	Area	Activity	Duration	Start	Finish
235	Area D 1st Floor	Blockfill & Painting	15 days	Wed 2/29/12	Tue 3/20/12
236	Area D 1st Floor	Insulate Ductwork & Piping	20 days	Thu 3/1/12	Wed 3/28/12
237	Area D 1st Floor	Install Drywall	10 days	Thu 3/22/12	Wed 4/4/12
238	Area D 1st Floor	Install Ceiling Grid	15 days	Fri 4/13/12	Thu 5/3/12
239	Area D 1st Floor	Install Sprinkler Drop Heads	14 days	Thu 4/26/12	Tue 5/15/12
240	Area D 1st Floor	Install Resinous Flooring	6 days	Fri 5/4/12	Fri 5/11/12
241	Area D 1st Floor	Install Light Fixtures & Devices	15 days	Tue 4/24/12	Mon 5/14/12
242	Area D 1st Floor	Install Duct Drops	22 days	Fri 4/20/12	Mon 5/21/12
243	Area D 1st Floor	Ceiling Tile	10 days	Tue 5/22/12	Mon 6/4/12
244	Area D 1st Floor	Fire Alarm, Security, Data, Sound, Clock, Classroom Media Finishes	13 days	Tue 6/5/12	Thu 6/21/12
245	Area D 1st Floor	Casework & Lockers	8 days	Fri 6/1/12	Tue 6/12/12
246	Area D 1st Floor	Flooring	15 days	Fri 6/8/12	Thu 6/28/12
247	Area D 1st Floor	Plumbing Fixtures & Toilet Specialties	22 days	Wed 6/13/12	Thu 7/12/12
248	Area D 1st Floor	Doors & Hardware	5 days	Wed 7/18/12	Tue 7/24/12
249	Area D 1st Floor	Classroom Specialties	5 days	Fri 7/13/12	Thu 7/19/12
250	Area D 2nd Floor	Install Joists & Deck	10 days	Tue 11/8/11	Mon 11/21/11
251	Area D 2nd Floor	Prep & Place Slab on Deck	6 days	Wed 11/23/11	Wed 11/30/11
252	Area D 2nd Floor	Masonry Bearing Walls to Roof	25 days	Thu 12/1/11	Wed 1/4/12
253	Area D 2nd Floor	Plumbing, Electrical, & Low Voltage in Wall Rough-Ins & Chases	25 days	Thu 12/1/11	Wed 1/4/12
254	Area D 2nd Floor	Install Door Frames	5 days	Thu 12/1/11	Wed 12/7/11
255	Area D 2nd Floor	Install Roof Joists & Roof Deck	15 days	Mon 1/9/12	Fri 1/27/12
256	Area D 2nd Floor	Spray Foam Insulation Ground to Roof	15 days	Fri 1/27/12	Thu 2/16/12
257	Area D 2nd Floor	HVAC Ducts, Pipes, Hangers, Mains, Branches	20 days	Mon 1/30/12	Fri 2/24/12
258	Area D 2nd Floor	Roofing & Roof Drains	21 days	Tue 1/31/12	Tue 2/28/12
259	Area D 2nd Floor	Overhead Electrical Rough-In	20 days	Thu 2/2/12	Wed 2/29/12
260	Area D 2nd Floor	Install Windows/Curtainwall Ground to Roof	20 days	Thu 2/2/12	Wed 2/29/12
261	Area D 2nd Floor	Brick Veneer Ground to Roof	20 days	Sat 2/4/12	Thu 3/1/12
262	Area D 2nd Floor	Sprinkler Rough-In and Branch Piping	13 days	Wed 2/15/12	Fri 3/2/12
263	Area D 2nd Floor	Dom. Water RI and Branch Piping	25 days	Tue 2/21/12	Mon 3/26/12

ID	Area	Activity	Duration	Start	Finish
264	Area D 2nd Floor	Set Roof Top Units & Misc. Equip.	4 days	Wed 2/22/12	Mon 2/27/12
265	Area D 2nd Floor	Install Mech. Equipment	4 days	Mon 2/27/12	Thu 3/1/12
266	Area D 2nd Floor	Install LV Cable Tray & Pull Wire	9 days	Tue 2/28/12	Fri 3/9/12
267	Area D 2nd Floor	Insulate Ductwork & Piping	16 days	Thu 3/1/12	Thu 3/22/12
268	Area D 2nd Floor	Metal Studs & Drywall	10 days	Thu 3/1/12	Wed 3/14/12
269	Area D 2nd Floor	Fire Alarm, Security, Data, Sound, Clock, Classroom Media Cabling	20 days	Tue 3/6/12	Mon 4/2/12
270	Area D 2nd Floor	Apply Block Filler & Paint	10 days	Wed 3/21/12	Tue 4/3/12
271	Area D 2nd Floor	Equipment Tie-Ins, Ductwork & Piping	8 days	Fri 3/2/12	Tue 3/13/12
272	Area D 2nd Floor	Wire HVAC Equipment	7 days	Mon 3/12/12	Tue 3/20/12
273	Area D 2nd Floor	Install Ceiling Grid	15 days	Fri 3/23/12	Thu 4/12/12
274	Area D 2nd Floor	Install Light Fixtures & Devices	17 days	Fri 3/30/12	Mon 4/23/12
275	Area D 2nd Floor	Install Duct Drops	16 days	Fri 3/30/12	Fri 4/20/12
276	Area D 2nd Floor	Install Sprinkler Drop Heads	7 days	Tue 4/3/12	Wed 4/11/12
277	Area D 2nd Floor	Install Resinous Flooring	6 days	Fri 4/13/12	Fri 4/20/12
278	Area D 2nd Floor	Ceiling Tile	10 days	Wed 4/25/12	Tue 5/8/12
279	Area D 2nd Floor	Casework & Lockers	8 days	Wed 5/9/12	Fri 5/18/12
280	Area D 2nd Floor	Fire Alarm, Security, Data, Sound, Clock, Classroom Media Finishes	12 days	Wed 4/25/12	Thu 5/10/12
281	Area D 2nd Floor	Flooring	10 days	Mon 5/21/12	Fri 6/1/12
282	Area D 2nd Floor	Plumbing Fixtures & Toilet Specialties	17 days	Wed 5/9/12	Thu 5/31/12
283	Area D 2nd Floor	Doors & Hardware	3 days	Fri 6/8/12	Tue 6/12/12
284	Area D 2nd Floor	Classroom Specialties	5 days	Fri 6/1/12	Thu 6/7/12



Appendix B

Site Layout Plans



NOTES

- The site exit/extrance are further down the access road
- The boundary line shown is where the site fencing has been place
- There is no pedestrian traffic on site
- There is no temporary lighting on site
- No overhead protection is required
- There are no surrounding buildings in the immediate area

Plan Legend

- Job Trailers for Primes
- Wash Station
- Traffic Pattern
- Fire Hydrant

Landis Run Intermediate School

Lancaster, PA

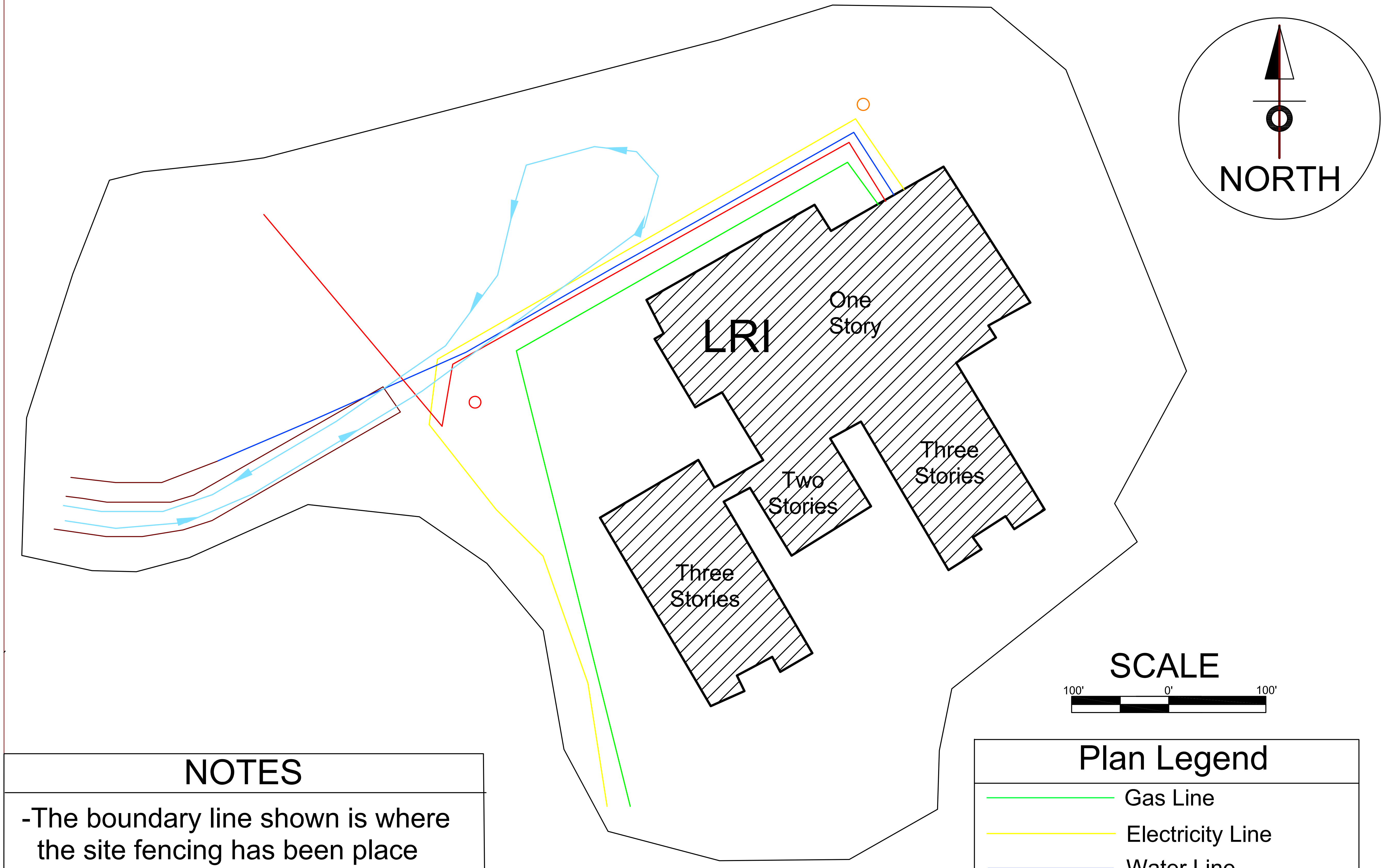
Matthew Stevenson

Construction Management

9/21/11

C102

Excavation Phase Conditions



Plan Legend

- Gas Line
- Electricity Line
- Water Line
- Communications Line
- Traffic Pattern
- Fire Hydrant

NOTES

- The boundary line shown is where the site fencing has been place
- There is no pedestrian traffic on site
- There is no temporary lighting on site
- No overhead protection is required
- There are no surrounding buildings in the immediate area

Landis Run Intermediate School

Lancaster, PA

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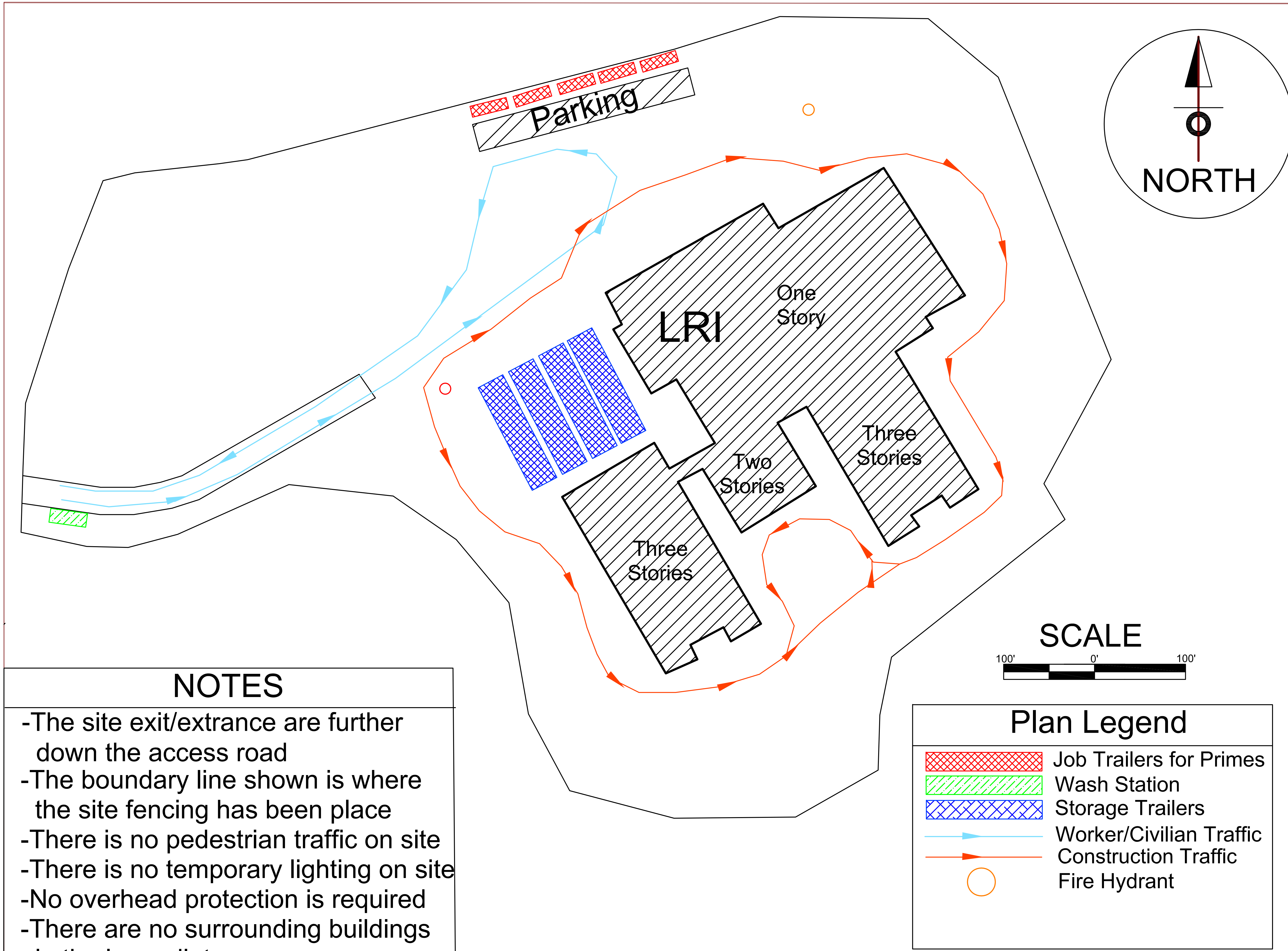
C101

Existing Conditions



NOTES

- The site exit/extrance are further down the access road
- The boundary line shown is where the site fencing has been place
- There is no pedestrian traffic on site
- There is no temporary lighting on site
- No overhead protection is required
- There are no surrounding buildings in the immediate area

Landis Run Intermediate School

Lancaster, PA

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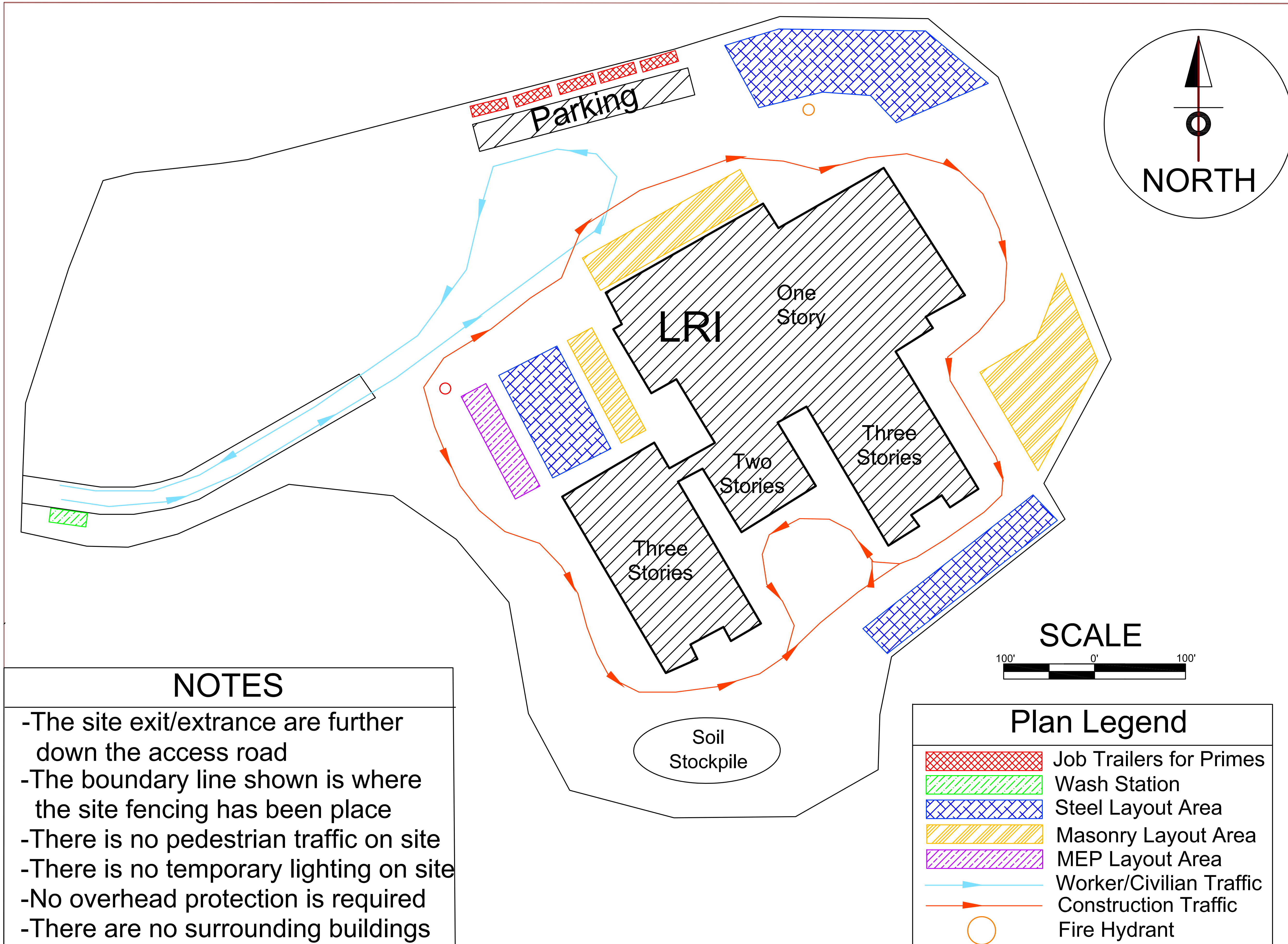
9/21/11

C104

Finishes Phase Site Plan



NOTES

- -The site exit/extrance are further down the access road
- -The boundary line shown is where the site fencing has been place
- -There is no pedestrian traffic on site
- -There is no temporary lighting on site
- -No overhead protection is required
- -There are no surrounding buildings in the immediate area

Landis Run Intermediate School
Lancaster, PA
Matthew Stevenson
Construction Management
9/21/11
C103
Superstructure Phase Site Plan

Appendix C

Detailed LEED Score Card

LEED 2009 for Schools New Construction and Major Renovations

Project Checklist

Landis Run Intermediate School

Y	?	N				
	1	0			**Sustainable Sites**	Possible Points: **20**
Y			C	Prereq 1	Construction Activity Pollution Prevention	
Y			d	Prereq 2	Environmental Site Assessment	
x			d	Credit 1	Site Selection	1
		x	d	Credit 2	Development Density and Community Connectivity	4
		x	d	Credit 3	Brownfield Redevelopment	1
x			d	Credit 4.1	Alternative Transportation—Public Transportation Access	1
x			d	Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	1
		x	d	Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	2
x			d	Credit 4.4	Alternative Transportation—Parking Capacity	1
			C	Credit 5.1	Site Development—Protect or Restore Habitat	1
			d	Credit 5.2	Site Development—Maximize Open Space	1
x			d	Credit 6.1	Stormwater Design—Quantity Control	1
x			d	Credit 6.2	Stormwater Design—Quality Control	1
			C	Credit 7.1	Heat Island Effect—Non-roof	1
x			d	Credit 7.2	Heat Island Effect—Roof	1
x			d	Credit 8	Light Pollution Reduction	1
x			d	Credit 9	Site Master Plan	1
x			d	Credit 10	Joint Use of Facilities	1

Y	?	N				
		5			**Water Efficiency**	Possible Points: **11**
Y			d	Prereq 1	Water Use Reduction—20% Reduction	
x			d	Credit 1	Water Efficient Landscaping	2 to 4
				x	50% Reduction	1
				x	No Potable Water Use or Irrigation	1
		x	d	Credit 2	Innovative Wastewater Technologies	2
x			d	Credit 3	Water Use Reduction	2 to 4
				x	30% Reduction	1
				x	35% Reduction	1
				x	40% Reduction	1
		x	d	Credit 3	Process Water Use Reduction	1

Y	?	N				
	1	1	**Energy and Atmosphere**		Possible Points:	**33**

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

Y	?	N				
		8		**Materials and Resources**	Possible Points:	**13**
Y			d	Prereq 1	Storage and Collection of Recyclables	
		x	C	Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 2
				[ ]	Reuse 75%	1
				[ ]	Reuse 95%	2
		x	C	Credit 1.2	Building Reuse—Maintain 50% of Interior Non-Structural Elements	1
x			C	Credit 2	Construction Waste Management	1 to 2
				x	50% Recycled or Salvaged	1
				x	75% Recycled or Salvaged	2
		x	C	Credit 3	Materials Reuse	1 to 2
				[ ]	5% Reuse	1
				[ ]	10% Reuse	2
x			C	Credit 4	Recycled Content	1 to 2
				x	10% of Content	1
				x	20% of Content	2
x			C	Credit 5	Regional Materials	1 to 2
				x	10% of Materials	1
				x	20% of Materials	2
x			C	Credit 6	Rapidly Renewable Materials	1
x			C	Credit 7	Certified Wood	1

	1	5	Indoor Environmental Quality		Possible Points: 19
Y	?	N			
Y			d	Prereq 1 Minimum Indoor Air Quality Performance	
Y			d	Prereq 2 Environmental Tobacco Smoke (ETS) Control	
Y			d	Prereq 3 Minimum Acoustical Performance	
x			d	Credit 1 Outdoor Air Delivery Monitoring	1
		x	d	Credit 2 Increased Ventilation	1
x			C	Credit 3.1 Construction IAQ Management Plan—During Construction	1
x			C	Credit 3.2 Construction IAQ Management Plan—Before Occupancy	1
x			C	Credit 4 Low-Emitting Materials	1 to 4
				x 4.1 - Adhesives & Sealants	1
				x 4.2 - Paints & Coatings	1
				x 4.3 - Flooring Systems	1
				x 4.4 - Composite Wood & Agrifiber Products	1
				4.5 - Furniture & Furnishings	1
				4.6 - Ceiling & Wall Systems	1
x			d	Credit 5 Indoor Chemical and Pollutant Source Control	1
x			d	Credit 6.1 Controllability of Systems—Lighting	1
x			d	Credit 6.2 Controllability of Systems—Thermal Comfort	1
x			d	Credit 7.1 Thermal Comfort—Design	1
x			d	Credit 7.2 Thermal Comfort—Verification	1
x			d	Credit 8.1 Daylight and Views—Daylight	1 to 3
				75% of classrooms	1
				x 90% of classrooms	2
				x 75% of other spaces	2 to 3
		x	d	Credit 8.2 Daylight and Views—Views	1
		x	d	Credit 9 Enhanced Acoustical Performance	1
x			d	Credit 10 Mold Prevention	1

Y	?	N				Points
		3			**Innovation and Design Process**	Possible Points: **6**
x			d/C	Credit 1.1	Innovation in Design: Integrated Pest Management	1
		x	d/C	Credit 1.2	Innovation in Design: Specific Title	1
		x	d/C	Credit 1.3	Innovation in Design: Specific Title	1
		x	d/C	Credit 1.4	Innovation in Design: Specific Title	1
x			d/C	Credit 2	LEED Accredited Professional	1
x			d/C	Credit 3	The School as a Teaching Tool	1

Y	?	N				Points
		0			**Regional Priority Credits**	Possible Points: **4**
		x	d/C	Credit 1.1	Regional Priority: Specific Credit	1
		x	d/C	Credit 1.2	Regional Priority: Specific Credit	1
		x	d/C	Credit 1.3	Regional Priority: Specific Credit	1
		x	d/C	Credit 1.4	Regional Priority: Specific Credit	1

Y	?	N		Points
0	5	2	**Total**	Possible Points: **110**

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

Appendix D – RS Means Mechanical Data

23 51 Breechings, Chimneys, and Stacks

23 51 33 – Insulated Sectional Chimneys

23 51 33.10	Prefabricated Insulated Sectional Chimneys	Crew	Daily Output	Labor-Hours	Unit	2012 Bare Costs Material	Labor	Equipment	Total	Total Incl O&P
9920	12" diameter	Q-10	30	.800	Ea.	18.95	39		57.95	82.50
9930	18" diameter		26	.923		24	45		69	97
9940	24" diameter		24	1		28	48.50		76.50	107
9950	30" diameter		20	1.200		32	58.50		90.50	127
9960	36" diameter		18	1.333		43	65		108	149
9962	42" diameter	Q-11	22	1.455		43	72		115	161
9964	48" diameter		20	1.600		51	79.50		130.50	181
9966	54" diameter		16	2		51	99.50		150.50	212
9968	60" diameter		12	2.667		56	132		188	270
9990	Minimum labor/equipment charge	Q-9	3	5.333	Job		250		250	395

23 52 Heating Boilers

23 52 13 – Electric Boilers

23 52 13.10	Electric Boilers, ASME	Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**ELECTRIC BOILERS, ASME**, Standard controls and trim R235000-50									
1000	Steam, 6 KW, 20.5 MBH	Q-19	1.20	20	Ea.	3,625	1,000		4,625	5,575
1040	9 KW, 30.7 MBH		1.20	20		3,775	1,000		4,775	5,725
1080	24 KW, 81.8 MBH		1.10	21.818		4,525	1,100		5,625	6,700
1160	60 KW, 205 MBH		1	24		6,250	1,225		7,475	8,750
1240	148 KW, 505 MBH		.65	36.923		9,000	1,875		10,875	12,800
1280	222 KW, 758 MBH		.55	43.636		13,500	2,200		15,700	18,300
1320	300 KW, 1023 MBH		.40	60		17,500	3,025		20,525	24,000
1360	444 KW, 1515 MBH		.30	80		20,200	4,050		24,250	28,500
1400	592 KW, 2020 MBH	Q-21	.34	94.118		25,800	4,875		30,675	36,000
1480	814 KW, 2778 MBH		.25	128		31,900	6,650		38,550	45,400
1520	1036 KW, 3536 MBH		.20	160		34,400	8,300		42,700	50,500
1560	2070 KW, 7063 MBH		.18	177		50,500	9,225		59,725	70,000
1600	2,340 KW, 7984 MBH		.16	200		65,500	10,400		75,900	88,000
2000	Hot water, 7.5 KW, 25.6 MBH	Q-19	1.30	18.462		3,825	935		4,760	5,650
2040	30 KW, 102 MBH		1.20	20		4,075	1,000		5,075	6,050
2070	60 KW, 205 MBH		1.20	20		4,800	1,000		5,800	6,875
2100	90 KW, 307 MBH		1.10	21.818		5,575	1,100		6,675	7,850
2140	120 KW, 410 MBH		.90	26.667		6,250	1,350		7,600	8,975
2180	150 KW, 512 MBH		.65	36.923		7,050	1,875		8,925	10,700
2220	296 KW, 1010 MBH		.55	43.636		11,900	2,200		14,100	16,500
2300	444 KW, 1515 MBH		.35	68.571		16,000	3,475		19,475	23,000
2340	518 KW, 1768 MBH	Q-21	.44	72.727		17,700	3,775		21,475	25,400
2420	740 KW, 2526 MBH		.39	82.051		21,400	4,250		25,650	30,200
2460	888 KW, 3031 MBH		.37	86.486		23,300	4,475		27,775	32,600
2500	1036 KW, 3536 MBH		.34	94.118		27,700	4,875		32,575	38,100
2540	1440 KW, 4915 MBH		.32	100		35,200	5,200		40,400	46,800
2580	1680 KW, 5733 MBH		.30	106		42,200	5,525		47,725	55,000
2620	1980 KW, 6757 MBH		.28	114		47,500	5,925		53,425	61,500
2660	2220 KW, 7576 MBH		.26	123		55,000	6,375		61,375	70,000
2700	2610 KW, 8905 MBH		.24	133		62,000	6,925		68,925	79,500
2740	2970 KW, 10133 MBH		.21	152		66,500	7,900		74,400	85,500
2780	3240 KW, 11055 MBH		.18	177		74,000	9,225		83,225	96,000
2820	3600 KW, 12,283 MBH		.16	200		81,500	10,400		91,900	105,500
9000	Minimum labor/equipment charge	Q-20	1	20	Job		955		955	1,500

3 64 Packaged Water Chillers

3 64 13 – Absorption Water Chillers

Line	3 64 13.16 Indirect-Fired Absorption Water Chillers	Crew	Daily Output	Labor-Hours	Unit	2012 Bare Costs Material	Labor	Equipment	Total	Total Incl O&P
00	955 ton	Q-7	.08	410	Ea.	649,500	21,800		671,300	748,500
00	1125 ton		.08	421		750,000	22,300		772,300	860,000
00	1250 ton		.07	444		806,500	23,600		830,100	923,500
00	1465 ton		.07	463		956,000	24,600		980,600	1,090,500
00	1660 ton		.07	477		1,125,000	25,300		1,150,300	1,277,000
00	For two stage unit, add					80%	25%			
00	Minimum labor/equipment charge	Q-5	1	16	Job		800		800	1,250

3 64 16 – Centrifugal Water Chillers

Line	3 64 16.10 Centrifugal Type Water Chillers	Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
10	**CENTRIFUGAL TYPE WATER CHILLERS**, With standard controls									
20	Centrifugal liquid chiller, water cooled									
30	not including water tower R262213-27									
00	2000 ton (twin 1000 ton units)	Q-7	.07	477	Ea.	865,500	25,300		890,800	991,500
274	Centrifugal, packaged unit, water cooled, not incl. tower									
280	400 ton	Q-7	.11	283	Ea.	129,500	15,000		144,500	166,000
320	1000 ton		.09	372		433,000	19,700		452,700	506,500
340	1300 ton		.08	410		547,000	21,800		568,800	636,000
360	1500 ton		.08	426		631,500	22,600		654,100	730,000

3 64 19 – Reciprocating Water Chillers

Line	3 64 19.10 Reciprocating Type Water Chillers	Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
010	**RECIPROCATING TYPE WATER CHILLERS**, With standard controls									
494	Water chillers, integral air cooled condenser									
546	70 ton cooling	Q-7	.27	119	Ea.	54,500	6,350		60,850	70,000
554	90 ton cooling		.25	125		63,500	6,675		70,175	80,000
600	100 ton cooling		.25	129		71,500	6,850		78,350	89,000
620	110 ton cooling		.24	132		76,500	7,025		83,525	95,000
630	130 ton cooling		.24	135		91,000	7,150		98,150	111,000
640	150 ton cooling		.23	137		101,000	7,325		108,325	122,500
650	175 ton cooling		.23	140		113,000	7,475		120,475	136,000
654	190 ton cooling		.22	144		124,500	7,650		132,150	149,000
660	210 ton cooling		.22	148		128,000	7,850		135,850	153,000
662	250 ton cooling		.21	151		148,500	8,050		156,550	176,000
664	275 ton cooling		.21	156		154,000	8,275		162,275	182,000
666	300 ton cooling		.20	160		172,000	8,475		180,475	202,500
668	330 ton cooling		.20	164		201,000	8,700		209,700	234,500
670	360 ton cooling		.19	168		221,000	8,925		229,925	257,000
672	390 ton cooling		.19	172		234,000	9,175		243,175	272,000
674	420 ton cooling		.18	177		244,500	9,425		253,925	283,500
980	Water cooled, multiple compressor, semi-hermetic, tower not incl.									
000	15 ton cooling	Q-6	.36	65.934	Ea.	17,500	3,425		20,925	24,700
020	25 ton cooling	Q-7	.41	78.049		18,900	4,150		23,050	27,300
040	28 ton cooling		.36	89.888		20,200	4,775		24,975	29,600
060	35 ton cooling		.31	101		22,600	5,400		28,000	33,200
080	40 ton cooling		.30	108		30,200	5,725		35,925	42,100
100	50 ton cooling		.28	113		32,300	6,050		38,350	44,900
120	60 ton cooling		.25	125		35,400	6,675		42,075	49,300
130	75 ton cooling		.23	139		48,900	7,375		56,275	65,500
140	85 ton cooling		.21	151		51,000	8,050		59,050	68,500
150	95 ton cooling		.19	164		54,500	8,750		63,250	73,500
160	100 ton cooling		.18	179		58,500	9,525		68,025	79,500
170	115 ton cooling		.17	190		61,500	10,100		71,600	83,000
180	125 ton cooling		.16	196		66,500	10,400		76,900	89,000

23 64 Packaged Water Chillers

23 64 26 – Rotary-Screw Water Chillers

23 64 26.10 Rotary-Screw Type Water Chillers		Crew	Daily Output	Labor-Hours	Unit	2012 Bare Costs Material	Labor	Equipment	Total	Total Incl O&P
0132	210 ton	Q-7	.12	258	Ea.	132,000	13,700		145,700	166,500
0136	270 ton		.12	266		150,500	14,100		164,600	188,000
0140	320 ton		.12	275		189,000	14,600		203,600	231,000
0240	200 ton	↓	.13	251	↓	82,000	13,400		95,400	111,000
1450	Water cooled, tower not included									
1560	135 ton cooling, screw compressors	Q-7	.14	235	Ea.	57,500	12,500		70,000	83,000
1580	150 ton cooling, screw compressors		.13	240		67,000	12,800		79,800	93,500
1620	200 ton cooling, screw compressors		.13	250		92,000	13,300		105,300	122,000
1660	291 ton cooling, screw compressors	↓	.12	260	↓	96,000	13,800		109,800	127,500

23 64 33 – Direct Expansion Water Chillers

23 64 33.10 Direct Expansion Type Water Chillers		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**DIRECT EXPANSION TYPE WATER CHILLERS**, With standard controls									
9000	Minimum labor/equipment charge	Q-6	1	24	Job		1,250		1,250	1,950

23 65 Cooling Towers

23 65 13 – Forced-Draft Cooling Towers

23 65 13.10 Forced-Draft Type Cooling Towers		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**FORCED-DRAFT TYPE COOLING TOWERS**, Packaged units R262213-27									
0070	Galvanized steel									
0080	Induced draft, crossflow									
0100	Vertical, belt drive, 61 tons	Q-6	90	.267	TonAC	197	13.85		210.85	238
0150	100 ton		100	.240		190	12.50		202.50	228
0200	115 ton		109	.220		165	11.45		176.45	200
0250	131 ton		120	.200		198	10.40		208.40	234
0260	162 ton	↓	132	.182	↓	160	9.45		169.45	192
1000	For higher capacities, use multiples									
1500	Induced air, double flow									
1900	Vertical, gear drive, 167 ton	Q-6	126	.190	TonAC	156	9.90		165.90	186
2000	297 ton		129	.186		96	9.65		105.65	121
2100	582 ton		132	.182		53.50	9.45		62.95	73.50
2150	849 ton		142	.169		72	8.80		80.80	92.50
2200	1016 ton	↓	150	.160	↓	72.50	8.30		80.80	93
3000	For higher capacities, use multiples									
3500	For pumps and piping, add	Q-6	38	.632	TonAC	98.50	33		131.50	159
4000	For absorption systems, add				"	75%	75%			
5000	Fiberglass tower on galvanized steel support structure									
5010	Draw thru									
5100	100 ton	Q-6	1.40	17.143	Ea.	10,100	890		10,990	12,500
5120	120 ton		1.20	20		11,700	1,050		12,750	14,500
5140	140 ton		1	24		12,700	1,250		13,950	16,000
5160	160 ton		.80	30		14,100	1,550		15,650	17,900
5180	180 ton		.65	36.923		16,000	1,925		17,925	20,600
5200	200 ton	↓	.48	50	↓	18,100	2,600		20,700	24,000
5300	For stainless steel support structure, add					30%				
5360	For higher capacities, use multiples of each size									
6000	Stainless steel									
6010	Induced draft, crossflow, horizontal, belt drive									
6100	57 ton	Q-6	1.50	16	Ea.	25,300	830		26,130	29,100
6120	91 ton		.99	24.242		30,600	1,250		31,850	35,600
6140	111 ton		.43	55.814		38,900	2,900		41,800	47,200

Appendix E – Boiler, Chiller, Cooling Tower Costs

Interpolation for boilers:

Eqn. E.1
$$\frac{(2616\ MBH - 2526\ MBH)}{(3010\ MBH - 2526\ MBH)} = \frac{(Unit\ Cost - \$30{,}200)}{(\$32{,}600 - 30{,}200)}$$

Solving equation E.1 for Unit Cost yields $30, 646.

The total cost for both boilers is therefore $61,292.

Interpolation for the cooling tower:

Eqn. E.2
$$\frac{(459\ Ton - 297\ Ton)}{(582\ Ton - 297\ Ton)} = \frac{(TonAC\ Cost - \$121)}{(73.50 - \$121)}$$

Solving equation E.2 for TonAC Cost yields $94 per Ton of AC.

The total cost for the cooling tower is therefore $43,146 since it has a nominal capacity of 459 Tons.

Appendix F – RS Means Electrical Data

26 05 Common Work Results for Electrical

26 05 29 – Hangers and Supports for Electrical Systems

26 05 29.20 Hangers		Crew	Daily Output	Labor-Hours	Unit	2012 Bare Costs Material	Labor	Equipment	Total	Total Incl O&P
5300	4′ long	1 Elec	10	.800	Ea.	28	41		69	94.50
5350	6′ long		8	1		42	51.50		93.50	126
5400	90° angle fitting 2-1/8″ x 2-1/8″		60	.133		4.01	6.85		10.86	15
5450	Supports, suspension rod type, small		60	.133		16.05	6.85		22.90	28.50
5500	Large		40	.200		17.65	10.30		27.95	35.50
5550	Beam clamp, small		60	.133		6.75	6.85		13.60	18.05
5600	Large		40	.200		7.65	10.30		17.95	24.50
5650	U-support, small		60	.133		4	6.85		10.85	15
5700	Large		40	.200		12.55	10.30		22.85	30
5750	Concrete insert, cast, for up to 1/2″ threaded rod		16	.500		3.88	26		29.88	44.50
5800	Beam clamp, 1/4″ clamp, for 1/4″ threaded drop rod		32	.250		2.85	12.90		15.75	23
5900	3/8″ clamp, for 3/8″ threaded drop rod		32	.250		9.50	12.90		22.40	30.50
6000	Strap, rigid conduit, 1/2″ diameter		540	.015		1.82	.76		2.58	3.18
6050	3/4″ diameter		440	.018		2.05	.94		2.99	3.71
6100	1″ diameter		420	.019		2.19	.98		3.17	3.93
6150	1-1/4″ diameter		400	.020		2.54	1.03		3.57	4.38
6200	1-1/2″ diameter		400	.020		3.07	1.03		4.10	4.97
6250	2″ diameter		267	.030		3.32	1.54		4.86	6.05
6300	2-1/2″ diameter		267	.030		3.83	1.54		5.37	6.60
6350	3″ diameter		160	.050		4.22	2.58		6.80	8.60
6400	3-1/2″ diameter		133	.060		5.60	3.10		8.70	10.95
6450	4″ diameter		100	.080		5.90	4.12		10.02	12.80
6500	5″ diameter		80	.100		12.25	5.15		17.40	21.50
6550	6″ diameter		60	.133		13.85	6.85		20.70	26
6600	EMT, 1/2″ diameter		540	.015		1.84	.76		2.60	3.20
6650	3/4″ diameter		440	.018		1.96	.94		2.90	3.61
6700	1″ diameter		420	.019		2.19	.98		3.17	3.93
6750	1-1/4″ diameter		400	.020		2.45	1.03		3.48	4.29
6800	1-1/2″ diameter		400	.020		3.03	1.03		4.06	4.92
6850	2″ diameter		267	.030		3.43	1.54		4.97	6.15
6900	2-1/2″ diameter		267	.030		3.65	1.54		5.19	6.40
6950	3″ diameter		160	.050		3.95	2.58		6.53	8.35
6970	3-1/2″ diameter		133	.060		4.41	3.10		7.51	9.65
6990	4″ diameter		100	.080		5.05	4.12		9.17	11.95
7000	Clip, 1 hole for rigid conduit, 1/2″ diameter		500	.016		.78	.82		1.60	2.13
7050	3/4″ diameter		470	.017		1.13	.88		2.01	2.60
7100	1″ diameter		440	.018		1.41	.94		2.35	3
7150	1-1/4″ diameter		400	.020		3.03	1.03		4.06	4.92
7200	1-1/2″ diameter		355	.023		3.49	1.16		4.65	5.65
7250	2″ diameter		320	.025		6.80	1.29		8.09	9.50
7300	2-1/2″ diameter		266	.030		15.15	1.55		16.70	19.10
7350	3″ diameter		160	.050		21.50	2.58		24.08	28
7400	3-1/2″ diameter		133	.060		31	3.10		34.10	39
7450	4″ diameter		100	.080		69.50	4.12		73.62	83
7500	5″ diameter		80	.100		217	5.15		222.15	247
7550	6″ diameter		60	.133		233	6.85		239.85	267
7820	Conduit hangers, with bolt & 12″ rod, 1/2″ diameter		150	.053		5.55	2.75		8.30	10.35
7830	3/4″ diameter		145	.055		5.60	2.84		8.44	10.55
7840	1″ diameter		135	.059		6.15	3.05		9.20	11.50
7850	1-1/4″ diameter		120	.067		6.75	3.44		10.19	12.75
7860	1-1/2″ diameter		110	.073		7.25	3.75		11	13.80
7870	2″ diameter		100	.080		9.15	4.12		13.27	16.40
7880	2-1/2″ diameter		80	.100		9.60	5.15		14.75	18.50

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26 05 Common Work Results for Electrical

26 05 19 – Low-Voltage Electrical Power Conductors and Cables

26 05 19.20 Armored Cable		Crew	Daily Output	Labor-Hours	Unit	Material	2012 Bare Costs Labor	Equipment	Total	Total Incl O&P
9091	For health care facilities cable, add, minimum					5%				
9092	Maximum					20%				
9100	#8, 2 wire, stranded	1 Elec	1.80	4.444	C.L.F.	296	229		525	680
9110	3 wire, stranded		1.30	6.154		415	315		730	945
9120	4 wire, stranded		1.10	7.273		560	375		935	1,200
9130	#6, 2 wire, stranded		1.30	6.154		440	315		755	970
9200	600 volt, copper (MC) aluminum clad, #14, 2 wire		2.65	3.019		72.50	156		228.50	320
9210	3 wire		2.45	3.265		116	168		284	385
9220	4 wire		2.20	3.636		161	187		348	465
9230	#12, 2 wire		2.55	3.137		73	162		235	330
9240	3 wire		2.20	3.636		128	187		315	430
9250	4 wire		2	4		173	206		379	510
9260	#10, 2 wire		2.20	3.636		158	187		345	465
9270	3 wire		1.80	4.444		221	229		450	600
9280	4 wire		1.55	5.161		345	266		611	790
9600	Alum (MC) aluminum clad, #6, 3 conductor w/#6 grnd		1.67	4.790		335	247		582	750
9610	4 conductor w/#6 grnd		1.64	4.878		365	251		616	790
9620	#4, 3 conductor w/#6 grnd	2 Elec	2.86	5.594		350	288		638	830
9630	4 conductor w/#6 grnd		2.82	5.674		375	292		667	865
9640	#2, 3 conductor w/#4 grnd		2.50	6.400		400	330		730	950
9650	4 conductor w/#4 grnd		2.47	6.478		450	335		785	1,000
9660	#1, 3 conductor w/#4 grnd		2	8		515	410		925	1,200
9670	4 conductor w/#4 grnd		1.98	8.081		615	415		1,030	1,325
9680	1/0, 3 conductor w/#4 grnd		1.82	8.791		590	455		1,045	1,350
9690	4 conductor w/#4 grnd		1.79	8.939		715	460		1,175	1,500
9700	2/0, 3 conductor w/#4 grnd		1.75	9.143		620	470		1,090	1,425
9710	4 conductor w/#4 grnd		1.71	9.357		800	480		1,280	1,625
9720	3/0, 3 conductor w/#4 grnd		1.71	9.357		795	480		1,275	1,625
9730	4 conductor w/#4 grnd		1.67	9.581		995	495		1,490	1,875
9740	4/0, 3 conductor w/#2 grnd		1.67	9.581		895	495		1,390	1,750
9750	4 conductor w/#2 grnd		1.61	9.938		1,125	510		1,635	2,025
9760	250 kcmil, 3 conductor w/#1 grnd	3 Elec	2.42	9.917		1,150	510		1,660	2,050
9770	4 conductor w/#1 grnd		2.36	10.169		1,550	525		2,075	2,500
9775	300 kcmil, 4 conductor w/#1 grnd		2.22	10.811		1,650	555		2,205	2,675
9780	350 kcmil, 3 conductor w/1/0 grnd		2.19	10.959		1,300	565		1,865	2,300
9790	4 conductor w/1/0 grnd		2.10	11.429		1,900	590		2,490	2,975
9800	500 kcmil, 3 conductor w/#1 grnd		2.10	11.429		1,875	590		2,465	2,975
9810	4 conductor w/2/0 grnd		2	12		2,300	620		2,920	3,475
9840	750 kcmil, 3 conductor w/1/0 grnd		1.95	12.308		2,725	635		3,360	3,975
9850	4 conductor w/3/0 grnd		1.89	12.698		3,225	655		3,880	4,525
9900	Minimum labor/equipment charge	1 Elec	4	2	Job		103		103	159

26 05 19.25 Cable Connectors		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**CABLE CONNECTORS**									
0100	600 volt, nonmetallic, #14-2 wire	1 Elec	160	.050	Ea.	1.29	2.58		3.87	[illegible]
0200	#14-3 wire to #12-2 wire		133	.060		1.29	3.10		4.39	[illegible]
0300	#12-3 wire to #10-2 wire		114	.070		1.29	3.62		4.91	[illegible]
0400	#10-3 wire to #14-4 and #12-4 wire		100	.080		1.29	4.12		5.41	7.75
0500	#8-3 wire to #10-4 wire		80	.100		2.49	5.15		7.64	10.70
0600	#6-3 wire		40	.200		3.33	10.30		13.63	19.60
0800	SER aluminum, 3 #8 insulated + 1 #8 ground		32	.250		3.79	12.90		16.69	24
0900	3 #6 + 1 #6 ground		24	.333		3.77	17.20		20.97	[illegible]
1000	3 #4 + 1 #6 ground		22	.364		5.90	18.75		24.65	[illegible]

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26 05 Common Work Results for Electrical

26 05 19 – Low-Voltage Electrical Power Conductors and Cables

26 05 19.90 Wire			Crew	Daily Output	Labor-Hours	Unit	Material	2012 Bare Costs Labor	Equipment	Total	Total Incl O&P
0010	**WIRE**	R260519-90									
0020	600 volt, copper type THW, solid, #14		1 Elec	13	.615	C.L.F.	8.20	31.50		39.70	58
0030	#12			11	.727		12.40	37.50		49.90	71.50
0040	#10			10	.800		19.55	41		60.55	85
0050	Stranded, #14	R260519-92		13	.615		9.25	31.50		40.75	59
0100	#12			11	.727		14.20	37.50		51.70	73.50
0120	#10	R260533-22		10	.800		22.50	41		63.50	88
0140	#8			8	1		37	51.50		88.50	120
0160	#6			6.50	1.231		63	63.50		126.50	167
0180	#4		2 Elec	10.60	1.509		98.50	78		176.50	229
0200	#3			10	1.600		124	82.50		206.50	263
0220	#2			9	1.778		157	91.50		248.50	315
0240	#1			8	2		198	103		301	375
0260	1/0			6.60	2.424		247	125		372	465
0280	2/0			5.80	2.759		310	142		452	560
0300	3/0			5	3.200		390	165		555	685
0350	4/0			4.40	3.636		495	187		682	835
0400	250 kcmil		3 Elec	6	4		580	206		786	955
0420	300 kcmil			5.70	4.211		690	217		907	1,100
0450	350 kcmil			5.40	4.444		845	229		1,074	1,275
0480	400 kcmil			5.10	4.706		970	243		1,213	1,450
0490	500 kcmil			4.80	5		1,150	258		1,408	1,650
0500	600 kcmil			3.90	6.154		1,375	315		1,690	2,000
0510	750 kcmil			3.30	7.273		1,950	375		2,325	2,700
0520	1000 kcmil			2.70	8.889		2,775	460		3,235	3,750
0540	600 volt, aluminum type THHN, stranded, #6		1 Elec	8	1		28	51.50		79.50	111
0560	#4		2 Elec	13	1.231		34.50	63.50		98	136
0580	#2			10.60	1.509		47	78		125	172
0600	#1			9	1.778		68.50	91.50		160	218
0620	1/0			8	2		82.50	103		185.50	250
0640	2/0			7.20	2.222		97.50	115		212.50	284
0680	3/0			6.60	2.424		121	125		246	325
0700	4/0			6.20	2.581		134	133		267	355
0720	250 kcmil		3 Elec	8.70	2.759		164	142		306	400
0740	300 kcmil			8.10	2.963		227	153		380	485
0760	350 kcmil			7.50	3.200		231	165		396	510
0780	400 kcmil			6.90	3.478		270	179		449	575
0800	500 kcmil			6	4		297	206		503	645
0850	600 kcmil			5.70	4.211		375	217		592	750
0880	700 kcmil			5.10	4.706		435	243		678	855
0900	750 kcmil			4.80	5		500	258		758	950
0920	600 volt, copper type THWN-THHN, solid, #14		1 Elec	13	.615		8.20	31.50		39.70	58
0940	#12			11	.727		12.40	37.50		49.90	71.50
0960	#10			10	.800		19.55	41		60.55	85
1000	Stranded, #14			13	.615		9.35	31.50		40.85	59.50
1200	#12			11	.727		14.35	37.50		51.85	74
1250	#10			10	.800		22	41		63	88
1300	#8			8	1		33.50	51.50		85	117
1350	#6			6.50	1.231		57.50	63.50		121	161
1400	#4		2 Elec	10.60	1.509		90	78		168	219
1450	#3			10	1.600		114	82.50		196.50	252
1500	#2			9	1.778		143	91.50		234.50	299

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26 05 Common Work Results for Electrical

26 05 33 – Raceway and Boxes for Electrical Systems

26 05 33.13 Conduit		Crew	Daily Output	Labor-Hours	Unit	2012 Bare Costs Material	Labor	Equipment	Total	Total Incl O&P
8750	2″ diameter				Ea.	45.50			45.50	50
8760	2-1/2″ diameter					203			203	224
8770	3″ diameter					254			254	280
8780	3-1/2″ diameter					415			415	455
8790	4″ diameter					425			425	465
8800	Box connectors, compression, 1/2″ diam., steel	1 Elec	120	.067		4.18	3.44		7.62	9.90
8810	3/4″ diameter		110	.073		5.85	3.75		9.60	12.25
8820	1″ diameter		90	.089		8.70	4.58		13.28	16.65
8830	1-1/4″ diameter		70	.114		22	5.90		27.90	33.50
8840	1-1/2″ diameter		60	.133		26	6.85		32.85	39
8850	2″ diameter		50	.160		37.50	8.25		45.75	54.50
8860	2-1/2″ diameter		36	.222		93	11.45		104.45	120
8870	3″ diameter		27	.296		128	15.25		143.25	165
8880	3-1/2″ diameter		21	.381		193	19.65		212.65	244
8890	4″ diameter		16	.500		198	26		224	258
8900	Box connectors, insulated compression, 1/2″ diam., steel		120	.067		4.03	3.44		7.47	9.75
8910	3/4″ diameter		110	.073		5.60	3.75		9.35	12
8920	1″ diameter		90	.089		9.40	4.58		13.98	17.45
8930	1-1/4″ diameter		70	.114		19	5.90		24.90	30
8940	1-1/2″ diameter		60	.133		28.50	6.85		35.35	42
8950	2″ diameter		50	.160		41.50	8.25		49.75	58.50
8960	2-1/2″ diameter		36	.222		108	11.45		119.45	137
8970	3″ diameter		27	.296		141	15.25		156.25	179
8980	3-1/2″ diameter		21	.381		207	19.65		226.65	258
8990	4″ diameter		16	.500		211	26		237	272
9100	PVC, schedule 40, 1/2″ diameter		190	.042	L.F.	1.12	2.17		3.29	4.58
9110	3/4″ diameter		145	.055		1.35	2.84		4.19	5.90
9120	1″ diameter		125	.064		2.30	3.30		5.60	7.65
9130	1-1/4″ diameter		110	.073		3	3.75		6.75	9.10
9140	1-1/2″ diameter		100	.080		3.44	4.12		7.56	10.15
9150	2″ diameter		90	.089		4.32	4.58		8.90	11.85
9160	2-1/2″ diameter		65	.123		7.95	6.35		14.30	18.55
9170	3″ diameter	2 Elec	110	.145		8.80	7.50		16.30	21.50
9180	3-1/2″ diameter		100	.160		12.20	8.25		20.45	26
9190	4″ diameter		90	.178		13	9.15		22.15	28.50
9200	5″ diameter		70	.229		18	11.80		29.80	38
9210	6″ diameter		60	.267		25	13.75		38.75	48.50
9220	Elbows, 1/2″ diameter	1 Elec	50	.160	Ea.	1.46	8.25		9.71	14.35
9230	3/4″ diameter		42	.190		1.43	9.80		11.23	16.70
9240	1″ diameter		35	.229		2.17	11.80		13.97	20.50
9250	1-1/4″ diameter		28	.286		3.35	14.75		18.10	26.50
9260	1-1/2″ diameter		20	.400		4.33	20.50		24.83	37
9270	2″ diameter		16	.500		5.85	26		31.85	46.50
9280	2-1/2″ diameter		11	.727		10.50	37.50		48	69.50
9290	3″ diameter		9	.889		17.60	46		63.60	90.50
9300	3-1/2″ diameter		7	1.143		23	59		82	116
9310	4″ diameter		6	1.333		28	68.50		96.50	137
9320	5″ diameter		4	2		46	103		149	210
9330	6″ diameter		3	2.667		106	137		243	330
9340	Field bends, 45° & 90°, 1/2″ diameter		45	.178			9.15		9.15	14.15
9350	3/4″ diameter		40	.200			10.30		10.30	15.95
9360	1″ diameter		35	.229			11.80		11.80	18.20
9370	1-1/4″ diameter		32	.250			12.90		12.90	19.90

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