Pershing Hill Elementary School

Fort Meade, MD

AE Senior Thesis 2010

April 7, 2010

Mitchell Reiners

Construction Management

Faculty Consultant: Dr. Magent

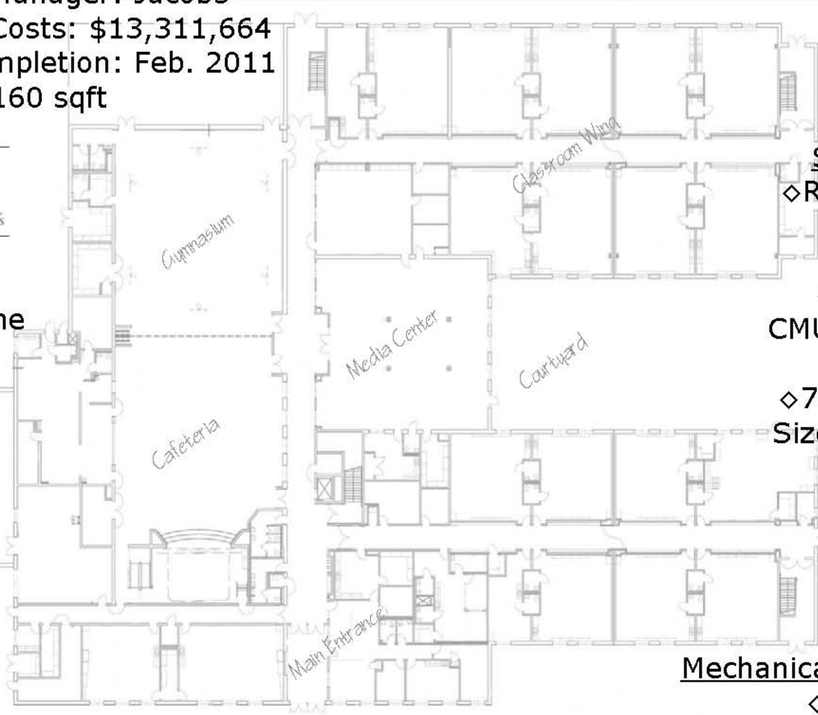
Pershing Hill Elementary School Fort Meade, MD

Project Team and Building Information

Owner: Anne Arundel County Public Schools
Tenant: Pershing Hill Elementary School
Architect: Grimm and Parker Associates
Construction Manager: Jacobs
Construction Costs: $13,311,664
Estimated Completion: Feb. 2011
Total size:87,160 sqft

Architectural

◇Multiple Colors of decorative brick
◇Curved aluminum canopy marks main entrance



ANNE ARUNDEL COUNTY PUBLIC SCHOOLS

Construction

◇Multiple prime with 15 prime contractors
◇Complete demolition of existing building
◇ Project site lies entirely within a US Army Base

Structural

◇Reinforced Concrete Footings
◇Grouted CMU exterior walls
◇7 Different Sizes of HSS shaped columns
◇Steel Joists and deck

Mechanical System

◇2 Boilers
◇11 Building Zones
◇46 Fan Coil Units
◇6 Ductless Split System Units
◇6 Rooftop Air Handling Units
◇2 Rooftop Air Handling Units with Energy Recovery

Electrical System

◇277/480V and 120/208V distribution
◇ Emergency Intercom available in each classroom

Site

◇A portion of the project site falls within a critical wetlands area

Mitchell Reiners Construction Management Option

http://www.engr.psu.edu/ae/thesis/portfolios/2010/mrr5025/index.html

Table of Contents

Acknowledgments

I would like to thank the following people for their help in achieving my senior thesis objectives this semester:

- The Faculty and Staff of the Penn State Architectural Engineering Department, and Dr. Magent for his advice and guidance throughout the year
- Anne Arundel County, for allowing me to study Pershing Hill Elementary School
- The Pershing Hill Elementary School Project Team including Ani Nigudkar, Andrew Locke, and Dennis Scholle for taking time to talk with me and for providing me with information about Pershing Hill Elementary School.
- Michael Arnold and Foreman University for the informative presentation on geothermal systems
- Heather Summerlin and Jonathan Richmond for their help with my CPEP website

Proposal Summery

Four analysis activities are executed in this paper; replacing the traditional roof with a green roof, installing a geothermal mechanical system, replacing the stick built masonry façade with a pre-fabricated system, and pursuing LEED certification. The green roof would address problems associated with storm water management, but would also provide additional load which would result in needing to redesign the structural system of a typical bay. A geothermal system would provide alternative energy, but at an additional upfront cost. Lifecycle analysis was used to weigh the additional upfront costs against the energy savings. A pre-fabricated system would involve less waste than stick-built masonry, but would require analyzing how the site could accommodate the additional requirements associated with pre-fabricated system. At the PACE Roundtable conference, it was discussed that many schools are moving towards LEED certification. The final analysis will look at the costs associated with pursuing LEED certification for Pershing Hill Elementary School, if the owner had decided to peruse LEED certification. This analysis will include looking at the possibility of a green roof and geothermal system, as they provide points towards LEED certification.

Executive Summary

This report includes four analysis activities for Pershing Hill Elementary school; replacing the traditional roof with a green roof, installing a geothermal mechanical system, replacing the stick built masonry façade with a pre-fabricated system, and pursuing LEED certification.

A green roof would offset the additional rainwater runoff due to the new building. To equalize the amount of runoff from the new building and existing structures would require a green roof with approximately 11.5 inches of growing media, which would represent a significant structural load. This green roof would result in the existing structural members needing to be resized, an increased need for coordination between the mechanical and roof contractors, and increased schedule duration for the roofing contractor.

A geothermal system would represent a significant upfront cost, as well as impact the project schedule. The internal rate of return was found to be less than 2% and would not be expected to beat inflation. This resulted in an estimated lifecycle cost of $271,412.27, based on a 3% annual inflation rate.

Preconstruction would have a favorable impact to the project schedule, but would have mixed effects on the constructability of the project. These effects include additional crane usage, additional coordination between the steel erector and masonry contractor, eliminating the need for scaffolding, and eliminating the need for cold weather construction techniques.

Perusing LEED Certification would result in additional cost for Pershing Hill Elementary School. The additional initial costs of 6.8% are much higher than the literature suggested. This is partially due to a difference in methods for tabulating the costs of perusing LEED certification.

Building Information

Pershing Hill Elementary School Replacement Project is the replacement of the existing school, which was built in 1960, and a consolidation with West Meade Elementary School at the same site. The state rated capacity of the existing school was 297 students, and the state rated capacity of the new school will be 733 students. The total costs to the owner are $15.1 million, and the construction costs are $13.3 million. Demolition of the existing school started on September 2, 2009 and substantial completion is scheduled for February 2011 with occupancy in August. The project is being delivered using the multiple-prime approach, which is required for public projects, with Jacobs acting at the construction manager.

Pershing Hill Elementary school is two stories. The first floor contains the spaces used by all students including: the gymnasium, cafeteria, media center, computer lab, music room, health room (also known as a nurse's office), principle's office, and classrooms. The second floor consists primarily of classrooms, but also contains the science room and faculty lounge. Outside of the entrance to the vestibule is a curved aluminum canopy, which is attached to the façade by a one inch hanger pipe assembly attached to embedded plates.

The first floor contains a large block to the North of the main hallway which contains the gymnasium and cafeteria (as well as the supporting facilities for these features). On the South side of the main hallway is the media center, which is attached to the computer lab. To the East and West of the media center are two wings which primarily contain classrooms, and closely follow the plan of the second floor wings. Because the entrance is to the West, the base of the west wing also contains the administrative offices.

The second floor consists of two wings and a hallway connecting them. The second floor hallway lies on top of the main hallway on the first floor, but there are no rooms to the north of it. This allows the gymnasium ceiling to rise in order to accommodate basketball games. Both wings are largely composed of classrooms on either side of the hallway. Four stairwells in total are located at the end of the hallway, as well as where it turns. The classrooms are on both sides of the hallway, and because they are along the wings of the building every classroom is open to natural light.

Building Enclosure

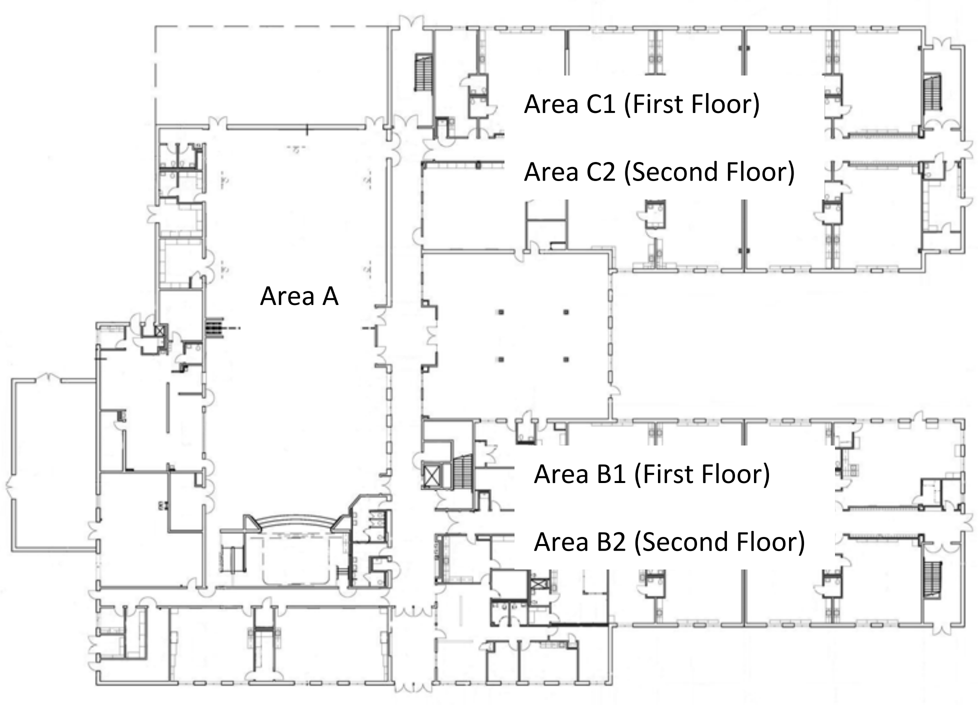
Building Facade: The exterior wall typically consists of a 4” brick veneer, 1¾” air space, 2” of extruded polystyrene insulation, and 8” CMU with a vapor retarder. Veneer ties are placed at a maximum of 16” on center, as are the weep holes. This is the typical system for the exterior walls, although it varies slightly at certain locations and the color of the brick changes throughout the building. The exterior brick comes in three different colors, with a lighter color being used on the second floor, and a darker decorative band running along the top of the walls on the second floor and gymnasium as well as along the top of the windows on the first floor. The building windows are made with aluminum frames and 1” insulated glazing.

The gymnasium and cafeteria wall are composed of the same system, but with minor modifications. The CMU in the gymnasium and cafeteria is 12” (as opposed to 8”) and the vapor retarder is replaced with a mastic vapor barrier.

Roofing: Built-up asphalt roofing is used on top of the roofing insulation throughout the building. The insulation rests on top of the steel deck, and is made of two layers. The top layer slopes, in order to direct the water on the roof to the drains.

Project Schedule Summary

The reinforced concrete footings will be poured in area B first, followed by area A and area C last. By sequencing the foundations in this manner, the contractor will be able to start on one part of the building and progress to the other side. The structural and finish sequences will follow the sequence A1, B1, C1, B2, C2 where the first floor is completed before work starts on the second floor. This also means that once one contractor is finished in area A, the next contractor can start. Since Area A is the largest, there is little chance that they will "catch up" while the previous contractor is working in areas B and C. A graphic display of the various sections of the building is shown below.



The critical path of the project includes site work, pouring concrete in the first area, placing CMU block at the foundation level, placing masonry bearing walls in Area A, structural steel erection, hanging ductwork and MEP rough-in, and drywall. All these activities, except for structural steel erection, could be accelerated by bringing in additional labor and working on multiple sections concurrently.

The key areas that have the potential to accelerate the schedule are those on the critical path, particularly those with long durations. The drywall instillation represents the largest potential for schedule acceleration, since drywall instillation is fully dependent on manpower. There is not a long lead time, allowing it to be accelerated on short notice, and the contractor can simply provide more manpower. This activity is expected to take between 25 and 30 days, so by accelerating it the construction manager could potentially save two or three weeks.

Constructability Challenges

For the Pershing Hill Elementary School Replacement Project, three constructability challenges were: a burn pit which was found under the building pad (made more difficult since soil could not be removed from the site), work next to a critical wetlands area, and the site being located within an active US Army base.

During site work, a burn pit was found directly under the building pad. This burn pit dated from the 1940’s or 50’s and contained tree trunks, branches, stumps and other organic debris that had been burned with diesel and buried on the site. This burn pit was 10,000 cubic yards, and took 12 days to undercut.

The Pershing Hill Elementary School Replacement Project involves work next to a “critical wetlands area.” This involves an additional permitting process, greater sediment controls, and additional oversight by the Maryland Department of the Environment (MDE). The additional sediment controls were included in the site contractor’s bid package.

Fort George G. Meade is an active US Army base, which brings several unusual constructability challenges including the possibility of a base lockdown and site access restrictions. The process for obtaining site access involved filling out a form that was included in the specifications, and submitting it to the construction manager. The construction manager, in turn submitted the forms to the AACPS liaison to FGGM.

Analysis 1: Green Roof

Introduction to Analysis

Storm water management is an important issue. The Pershing Hill Elementary School Replacement Project requires additional sediment controls during construction, because of its proximity to a “critical wetlands area.” The “critical wetlands area” will be preserved through construction. Following construction of the building, one of the sediment control ponds will be demolished to build the parking lot. The parking lot, and the school, will reduce the amount of green space, which will increase the amount of storm water runoff after construction. A green roof would help manage storm water runoff after construction, but would weigh significantly more than a traditional roof, resulting in increased building loads. A green roof will also take more time to construct than the current built up roofing.

System Preliminary Design

Green roofs are broadly divided as intensive and extensive green roofs. Intensive green roofs are characterized by a growing medium six inches or deeper, while extensive green roofs are characterized by a growing medium of less than six inches. The depth of the growing medium is significantly correlated to the amount of rainwater runoff while the age, slope angle, and length of the green roof are not significantly correlated (Jeroen Mentensa, Dirk Raesa and Martin Hermy 2005). Because intensive green roofs have lower average runoff, an intensive green roof will be used in this analysis.

The components of a typical green roof include the plants, growing media (soil), filter fabric, a drainage layer, a root barrier, insulation, a waterproofing membrane, and a structural deck (Dr. Richard A. Behr 2010).

The runoff percentage for a green roof is given by the equation: runoff in mm/year = 693-1.15(average annual rainfall in mm)+0.001(average annual rainfall in mm)^2-0.8 x depth of growing medium (in mm) (Jeroen Mentensa, Dirk Raesa and Martin Hermy 2005). While the runoff percentage for a normal roof is given by the equation: runoff in mm/year = 0.81(average annual rainfall in mm) for non-greened roofs (Jeroen Mentensa, Dirk Raesa and Martin Hermy 2005). The runoff coefficients for paved areas can range from 0.70 to 0.95 and the runoff coefficient for unimproved areas can range from 0.1 to 0.3 (Susan K. Weiler, Katrin Scholz-Barth 2009).

The existing school, that has been demolished, had a building footprint of 20,245 sqft, three trailers each with a footprint of approximately 850 sqft each, and approximately 38,400 sqft of paved area. In addition, the new school will also be a consolidation with West Meade Elementary School, which currently has a building footprint of approximately 42,500 sqft and four trailers of approximately 850 sqft each. Because the new school will hold the students from West Meade Elementary School, it will effectively “give back” that building. It is unlikely that the impervious surfaces will be demolished, or used as effectively by the new owner, so their area is not included.

The replacement school has a building footprint of 42,595 sqft and approximately 104,700 sqft of paved area. This represents approximately 86,100 sqft of land that was previously unimproved being improved upon. Using this information, it is possible to calculate how thick the growing medium should be, in order for the new building to produce the same amount of runoff as the existing building. Because the runoff coefficients for unimproved areas and paved areas have a range, I assumed them to be 0.2 and 0.8 respectively (in the middle of the ranges) in the following calculation:

Runoff (New Building) + Runoff (site) +Runoff (West Meade-Unimproved) = Runoff (Old Building)+ Runoff (site)+Runoff (West Meade Elementary)

Runoff Coefficient of Green Roof (42,595) + 0.8(104,700) + 0.2(42,500+4*850) = 0.81 (20,245)+0.81(3*850)+0.2(86,100)+0.8(38400)+0.81(42,500)+0.81(4*850)

Runoff Coefficient of Green Roof (42,595) + 92,940 = 103,583

Runoff Coefficient of Green Roof = 0.25

This means that the green roof must retain 75% of all rainfall over the course of the year, in order for the new building to produce no more runoff than the building it was replacing. The average yearly rainfall for the area is 1075 mm, so 25% runoff would be 269 mm. This is used to determine the growing medium depth in mm:

$269 = 693-1.15(1075)+0.001(1075)^2-0.8$ x depth of growing medium (mm)

$269 = 693-1.15(1075)+0.001(1075)^2-0.8$ x depth of growing medium (mm)

269 = 693-1236+1156-0.8 x depth of growing medium (mm)

269 = 612-0.8 x depth of growing medium (mm)

274 mm = depth of growing medium = 10.8 inches

This means that to balance the total amount of storm water runoff from before construction and after construction, the growing medium would need to be nearly 11 inches deep. 12 inches is normally required for grass areas, so typical green roof plants for the local environment would need to be selected. Based on a hardiness zone of six for Anne Arundel County, this would include delosperma nubigenum and talinum calycinum. For lawns and shrubs, the weight of the actual plants is typically considered insignificant in comparison to the weight of the soil required for them to grow (Susan K. Weiler, Katrin Scholz-Barth 2009).

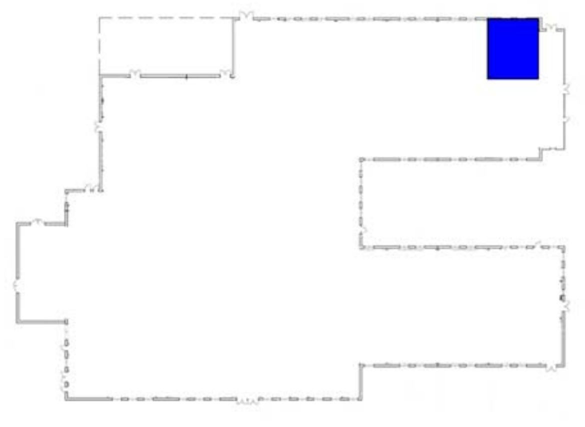
The weight of the soil is 120 pcf (Susan K. Weiler, Katrin Scholz-Barth 2009) and the size of the typical bay being redesigned is 29 feet 8 inches by 29 feet 9 inches (883 sqft). This means that the total weight of the growing medium over the typical bay will be 101,545 pounds.

For the drainage layer, the filter fabric is assumed to weigh 4 psf and the lightweight aggregates weigh up to 55 pcf (Susan K. Weiler, Katrin Scholz-Barth 2009). For a 3” drainage layer of crushed brick, this would result in a total weight for the typical bay of 15,673 pounds.

The additional soil increases the R-value of the roof, but by much less than the extruded polystyrene insulation. When an R-value analysis is done, the thickness of the polystyrene will not change from the current roof design. The insulation will add 0.5 psf per inch of thickness (Susan K. Weiler, Katrin Scholz-Barth 2009) which results in a total weight of 1766 pounds over the entire typical bay. The total dead load due to the roof components is 118,984 pounds, or 135 psf.

Structural Impacts

The additional weight of the green roof beyond the traditional roof means that the current structural design may not be sufficient if the green roof were added. The structural components from the typical bay from Technical Assignment 2 (below) will be analyzed to predict if the structural system will need to be redesigned.

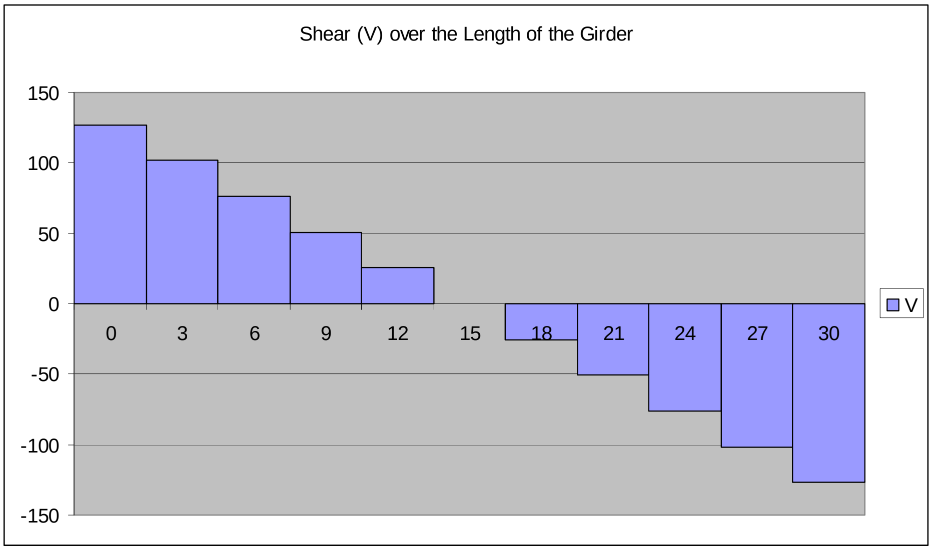


The design notes from drawing S2-1 list the design loads for the roof. It assumes a live load of 25 psf, a flat roof snow load of 22 psf. When these loads are added to the dead load of 135 psf, the total load is found to be 182 psf.

Drawing S2-1 notes that that the metal deck is designed to be continuous over three spans, and is to be 1½" 20 gauge deck. This is equivalent to a 1.5B20 metal deck from the Vulcraft catalog (Appendix A). That deck has a maximum span of 7'9", which is greater than the 5' span for the typical bay. However, 1.5B20 deck has a total allowable uniform load of only 165 psf, which is lea than the 182 psf needed, and not OK. The metal deck must be redesigned. A 1.5B19 (19 gauge deck) had a maximum span of 8'5" (greater than 5') and an allowable total uniform load of 193 psf (greater than the 182 psf needed). This deck weighs 2.5 psf, so it would increase the dead weight of the roof to 137.5 psf.

After the roof deck is selected, the joists for the second floor need to be analyzed. The LRFD method was used for this analysis. The total factored load is 1.2 (total dead load)+1.6(total live load). This gives a totaled factored load of 240.2 psf. With a 5' on center spacing (given from drawing S1-5) W_{TL}=240.2 x 5 =1201 plf and W_{LL}= 47x 5 =235 plf. The current design calls for 18KCS2 steel joists at 5 feet on center. LRFD tables for the KCS open web steel joists lists the maximum uniformly distributed load capacity as 825 plf (Appendix B). Because 1201 plf is greater than 825 plf, the current joists carrying the roof would not be sufficient if the proposed green roof was added. If the spacing of the joists was reduced to 3' on center W_{TL}=240.2 x 3 =720.6 plf and W_{LL}= 47x 3 =141 plf. Because 721 plf is less than 825 plf, this is acceptable.

When analyzing the girders that will carry the joists and roof, the weight of the joists must also be included. The weight of the joists is given from the LRFD table as 9lb/ft. The span of the joists can be rounded up to 30 feet, so that the total weight per joist is 270 lbs. This is multiplied by 10 joists total, divided by the floor area, and rounded up from 3.06 psf to 3.5 psf. This increases the dead load carried by the girders on the second floor to 141 psf. This gives a totaled factored load of 282 psf. P_u is calculated from this information. P_u = 282 (3')(30') = 25.4 kips. This can be used to graph the shear force, as shown below:



The maximum shear from this graph is found to be 127 kips. The Shear can be used to calculate the maximum moment. Because the moment is the integral of the shear, the maximum moment will occur at 15 feet (as can be seen in the above chart). By taking the integral of V from 0 to 15, the maximum moment is found to be 1143 kips*ft. These values are compared to the maximum values allowed in the Flexural Design Tables (Appendix C). The current design calls for W18 x 46 girders which are allowed a maximum shear of 195 kips and a maximum moment of 340 kips*ft. The 195 kips allowed are greater than the 127 kips calculated, but the 340 kips*ft allowed are less than the 1143 kips*ft calculated, so the girders would need to be resized. If the 18 inch depth is maintained, W18 x 143 girders must be used. If the most economical girder is chosen, a W30 x 99 would be used. For the remainder of this analysis, it will be assumed that W18 x 143 girders would be used.

The green roof will add additional weight to the roof, but not the second floor. As a result, the slab, joists, and girders that support the second floor will remain sufficient even if a green roof were added.

HSS columns are used and are sized differently for the interior and exterior. Because the exterior columns carry a smaller tributary area, they have a smaller size. The columns are assumed not to be spliced for this analysis. The exterior columns will be analyzed first.

The exterior columns will each have a tributary area of 441 sqft (29.75 x 29.67/2). The roof, decks, and joists represent a totaled factored load of 240.2 psf. The girder will weigh 143 lb per linear foot, which will result in a load of 4.25 Kips; which when factored will be 6.8 Kips. This results in a total factored load of 110.2 Kips from the roof. Because the columns are not spliced, though, they will also carry the weight from the second floor.

The design live loads for the classrooms from drawing S2-1 are 60 psf. The exterior columns only carry the weight from the classrooms. The second floor is supported by a deck with 3" normal weight concrete topping. The deck gives a weight of 2.5 psf, and the concrete topping adds a weight of 46 psf. The joists are 20K5 at 2'6" on center. The weight of the joists is found to be 8.2 lb/ft from the LRFD table (Appendix B), which equates to a weight of 3.2 psf. The weight of the W33 x 130 girder is 130 lb/ft which equates to 3.9 Kips. This means the total dead load due to structural members supporting the second floor is 51.7 psf plus 3.9 Kips, which results in an unfactored dead load of 26.7 Kips. This means that the total factored load, 1.2 (total dead load)+1.6(total live load), is 128 Kips. When added to the weight from the roof, this results in a total load of 238 Kips that must be carried. The current design calls for HSS 9 x 5 x 3/8 columns for the exterior, which can carry a maximum of 205 Kips according to the manufacturer's data (Appendix D). This is less than the 238 Kips required, so it would be insufficient for this analysis. HSS 9 x 5 x 1/2 columns can carry a maximum of 262 Kips, which would be sufficient for this analysis.

The interior columns will have a tributary area of 882 sqft. In addition, they will carry some of the weight from the corridor (which is west of the typical bay selected for this analysis). The corridor is approximately 11’ wide, and the design live load used for corridors was 80 psf according to drawing S2-1. This results in an additional live load (beyond that if it only supported classrooms) of 6.5 Kips, which becomes 10.5 Kips when factored. Because the interior columns have twice the tributary area, but the other loads are the same as the exterior columns the total load will be twice the exterior columns load plus the difference in live load for the corridor. This results in a load of 503 Kips. This load cannot be carried by 9x5 HSS columns, according to the manufacturer data, so a larger column would be required. There are several HSS column sizes that would be sufficient, so for this analysis 18 x 6 x 1/2 will be chosen.

Constructability Impacts

The largest constructability issue would be the increased soil and material brought to the roof. The construction of the roof coincides with the construction of the structural steel so that the crane can be used, although it would require sharing between the steel and roof contractor. The additional time spent by the roofing contractor would not interfere with the instillation of mechanical equipment on the roof, because the schedules of the contractors would not overlap. However, additional coordination between the roofing and mechanical contractor would be required so that the mechanical contractor is not required to dig up portions of the roof to place their equipment. This coordination would need to extend to mechanical equipment with penetrations in the roof.

Schedule Impacts

A green roof will have an impact on the schedule for the roofing contractor but not for the other trades, and will not affect the critical path. The project schedule for the roofing contractor without the green roof is shown on the left and the roofing schedule with the green roof is shown on the right. The durations for the additional activities were based on daily output from RS Means 2009 (Appendix E). Because the roof is enclosed relatively early in the green roof construction process, the waterproofing is installed before the drainage layer, the addition of a green roof has little effect on the activities of the other trades and did not effect the critical path or scheduled end date.

Roofing Contractor	1 day?	Wed 6/10/09	Wed 6/10/09
Submittals	22 days	Tue 9/1/09	Wed 9/30/09
Area A Roof Dry-In/Flashing at Gym/Cafeteria	3 days	Tue 3/2/10	Thu 3/4/10
Complete Roof Ballast at Gym/Café	4 days	Fri 3/5/10	Wed 3/10/10
Area A Roof Dry-In Flashing at Remaining Area A	4 days	Tue 4/13/10	Fri 4/16/10
Complete Roof Ballast at remaining area A	3 days	Mon 4/19/10	Wed 4/21/10
Fabricate Parapet Coping (All areas)	26 days	Mon 8/9/10	Mon 9/13/10
Install Parapet Coping	15 days	Tue 1/18/11	Mon 2/7/11
Area B Roof Dry-In	5 days	Wed 6/30/10	Tue 7/6/10
Complete B2 Roof Ballast	2 days	Wed 7/7/10	Thu 7/8/10
Area B Dry in at low area B1 Roof	2 days	Fri 7/9/10	Mon 7/12/10
Complete B1 Roof Ballast	2 days	Tue 7/13/10	Wed 7/14/10
Area C Roof Dry-In above Media Room	3 days	Wed 7/14/10	Fri 7/16/10
Comp Roof Ballast above Media Room	3 days	Mon 7/19/10	Wed 7/21/10
Area C Roof Dry-In at C2 Roof	5 days	Thu 8/12/10	Wed 8/18/10
Area C1 Downspout/Gutter/Facia/Soffit	2 days	Mon 8/16/10	Tue 8/17/10
Complete C2 Roof Ballast	3 days	Thu 8/19/10	Mon 8/23/10

Roofing Contractor	1 day?	Wed 6/10/09	Wed 6/10/09
Submittals	22 days	Tue 9/1/09	Wed 9/30/09
Area A Roof Dry-In/Flashing at Gym/Cafeteria	3 days	Tue 3/2/10	Thu 3/4/10
Install Roof Substrate at Gym/Café	3 days	Fri 3/5/10	Tue 3/9/10
Planting at Gym/Café	2 days	Wed 3/10/10	Thu 3/11/10
Area A Roof Dry-In Flashing at Remaining Area A	4 days	Tue 4/13/10	Fri 4/16/10
Install Roof Substrate at remaining area A	7 days	Mon 4/19/10	Tue 4/27/10
Planting at remaining Area A	4 days	Wed 4/28/10	Mon 5/3/10
Fabricate Parapet Coping (All areas)	26 days	Mon 8/9/10	Mon 9/13/10
Install Parapet Coping	15 days	Tue 1/18/11	Mon 2/7/11
Area B Roof Dry-In	5 days	Wed 6/30/10	Tue 7/6/10
Install Roof Substrate at B2 Roof	3 days	Wed 7/7/10	Fri 7/9/10
Plant at area B2 Roof	2 days	Mon 7/12/10	Tue 7/13/10
Area B Dry in at low area B1 Roof	2 days	Tue 7/13/10	Wed 7/14/10
Install Roof Substrate at area B1	3 days	Thu 7/15/10	Mon 7/19/10
Plant at Area B1	2 days	Tue 7/20/10	Wed 7/21/10
Area C Roof Dry-In above Media Room	3 days	Thu 7/22/10	Mon 7/26/10
Install Roof Substrate above Media Room	2 days	Tue 7/27/10	Wed 7/28/10
Plant above Media Room	1 day	Thu 7/29/10	Thu 7/29/10
Area C Roof Dry-In at C2 Roof	5 days	Thu 8/12/10	Wed 8/18/10
Area C1 Downspout/Gutter/Facia/Soffit	2 days	Mon 8/16/10	Tue 8/17/10
Install Roof Substrate At area C1	7 days	Thu 8/19/10	Fri 8/27/10
Plant at area C1	4 days	Mon 8/30/10	Thu 9/2/10

As can be seen by comparing these schedules, 9 additional work days are added to the roofing contractor’s schedule when the green roof is added. This is based on the assumption that there will be six crews of 1 laborer each. The additional time for the roofing contractor could be negated by hiring additional laborers. Additional workers in the same space can lead to decreased productivity (because of crowding). Because the schedule calls for the roofing to start once the entire area is ready, and there is about 72 feet in the shortest dimension, the roofing contractor can utilize up to up to 14 workers, assuming they need 5 feet each on average.

Conclusion

The additional amount of impervious area in the new building will contribute to a major increase in storm water runoff. One method to combat this is through the use of a green roof. To equalize the amount of runoff from the new building and existing structures would require a green roof with approximately 11.5 inches of growing media (in depth). This would represent a significant structural load that would result in the existing structural members needing to be resized. In addition, a green roof would result in an increased need for coordination between the mechanical and roof contractors, and increased schedule duration for the roofing contractor. This increased schedule duration could be offset by the use of additional crews.

Analysis 2: Geothermal System

Introduction to Analysis

As was discussed in the PACE Roundtable conference earlier this semester, new standards for energy performance are emerging and clients are becoming more aware of the energy impacts in their buildings. This is a critical industry issue. It was also discussed that builders are seeing more geothermal systems being implemented in schools, as a way to meet these energy demands, and alternative energy sources are becoming more popular due to government incentives. A geothermal mechanical system will provide alternative energy, and reduce the building's demand for outside energy. However, there are significant upfront costs associated with geothermal energy systems.

System Preliminary Design

Geothermal energy can be collected through the ground (direct expansion), or the transport of ground water. With a ground water system the highest coefficient of performance can be achieved and the best system is an open loop (Karl Ochsner 2008). However, the adequacy of water and temperature for this site was not tested, and the water quality can change over time (commonly due to fertilizer use), which is more likely to be a future problem with this building due to the long service life of the schools. For these reasons, a direct expansion system (which must be a closed loop) is chosen for this analysis. Although the water at the specific site was not tested, the soil is suitable for geothermal heat pumps (U.S. Department of Energy).

Most refrigerants installed in closed systems will be chlorine free due to the risk of leakage. Common refrigerants installed in geothermal systems include R134a, R407c, R410A and R404A (Karl Ochsner 2008). The refrigerant is normally installed during the manufacturing process, so an appropriate one will be chosen by the manufacturer.

When estimating the size of the geothermal system, the heating demand must be determined. Systems with ground heat collectors are operated as monovalent systems, where the heat pump provides 100% of the heating demand (Karl Ochsner 2008). The ground serves as an ideal heat source for monovalent systems since energy is available even in winter, including when the ground is covered in snow (Karl Ochsner 2008).

The conductive heat load for Pershing Hill Elementary can be found through R-Value Analysis. The R value Analysis from the H.A.M. Toolbox (Appendix F) was done for a typical wall section and gives an R value of 13.73. The climatic conditions from the H.A.M. Analysis gives an internal and external design temperature of 70 and 15ºF during the winter based on location. The Washington, DC location was used since that is the closest location to Ft. Meade.

Because the U value of the system is the inverse of the sum of the R values of the components, the U value of the wall is 0.73 BTU/(Hr x Ft^2 x ºF). The U value is multiplied by the area of the walls (below), and the 55ºF temperature difference to find the BTU needed per hour.

Walls	U-Values	Area (ft^2)	U*A
North	0.072833	6555	477.4217
South	0.072833	6555	477.4217
East	0.072833	8467.2	616.6934
West	0.072833	8467.2	616.6934
Roof	0.05	42592	2129.6
		Total	4317.83

When multiplied by the 55ºF temperature difference, 237,481 BTU/Hr are needed to heat the building during the winter. The heat transferred by geothermal heating is approximately 40 Watts per square meter of contact area (Karl Ochsner 2008). This corresponds to 18,722 square feet of surface area needed. The typical active depth of a geothermal borehole is 300 feet, with the pipes placed in an enhanced bentonite grout which has a thermal conductivity of 1.2 (Foreman University 2009). Given the typical active depth and an 8" hole diameter, 27 geothermal boreholes would need to be excavated.

Schedule Impacts

Based on the relevant RS Means data (Appendix E) it would take an estimated 19.3 days to install the pumps for the geothermal system, and 83.5 days for the additional excavation with a single crew. With four crews performing the additional excavation, and two crews installing the pumps, this would equate to 9.6 (round up to 10) days to install the pumps and 20.9 (round up to 21) days to perform the additional excavation. All of this time is on the critical path, so it would increase the duration of the project by 31 work days.

The additional time can be minimized by overlapping the additional excavation and instillation of the pumps. The project is divided into three areas for construction. By allowing the pump instillation to begin following the additional excavation in that area (and not waiting for the additional excavation to be completed over all areas before starting) the additional instillation time could be reduced to 25 workdays.

The additional time during excavation would result in additional general conditions (for the extra time on site) or the need to accelerate the schedule later in construction. The drywall instillation provides the greatest potential for schedule acceleration and could save 15 days (Mitchell Reiners 2009) by bringing in additional manpower and starting from two locations. For this analysis, it will be assumed the geothermal instillation adds 10 workdays to the critical path.

Life Cycle Analysis

To perform a life cycle analysis, the costs of the system are compared to the savings over the course of the building's use. The upfront costs of the geothermal system will include construction costs and additional general conditions due to the schedule impact. The additional construction costs for the 27 bores and pumps will be $686,475 based on the data from RS Means (Appendix E). The total general conditions were estimated to be $1,694,443 (Mitchell Reiners 2009). However not all elements will require additional cost, for example additional aerial photos may not be required. Temporary heating will not be required during this stage of the project, based on the project schedule. Temporary lighting and power will also not be required during excavation. The additional general conditions, based on 10 additional work days and an additional $49,548 to the project, are broken down on the following page:

		Cost	Quantity	Unit	Total
Staffing	Project Manager	2975	2	week	$5,950
	Superintendent	2750	2	week	$5,500
	Assistant Super.	2475	2	week	$4,950
	Project Engineer	1800	2	week	$3,600
	Clerk	590	2	week	$1,180
CM Fee		4.6		% of Project	$31,683
Temporary Utilities	Trailer Rental	310	0.5	month	$155
Field Office Expenses	Office Equipment	171	0.5	month	$86
	Office Supplies	94	0.5	month	$47
	Telephone bill	88	0.5	month	$44
	Lights and HVAC	165	0.5	month	$83
Estimated Cost	$53,277	Location Factor	0.93	**Total Cost**	**$49,548**

The additional upfront general conditions and construction costs are estimated at $736,023 based on this data. This is partially offset by $10,000 in a state rebate program for geothermal heat pumps (DSIRE). The original Pershing Hill Elementary school was first occupied in 1960 (Appendix G). This means the original school's life cycle was approximately 50 years. Therefore a 50 year life cycle will be used in the life cycle analysis.

The yearly savings are going to be dependent to the yearly energy need of the building. For Maryland and D.C. during the 2008/2009 heating year, there were 4889 degree days (U.S. Department of Commerce National Oceanic and Atmospheric Administration: National Environmental Satellite, Data, and Information Service 2010). Given the surface area and U-value of the building, this corresponds to 506,636,919 BTU per year. The cost for natural gas heating in 2007 was $1.218 per 100,000 BTU which corresponds to an annual heating cost of $6,171. As a rule of thumb one fourth of the energy needed to heat the building is used to run the geothermal pumps (Karl Ochsner 2008). With an electrical cost of $31.21 per million BTUs

(National Propane Gas Association) this corresponds to an annual cost of $3,953.03. In this analysis an annual energy escalation cost of 8% was assumed.

When a life cycle analysis is performed (Appendix H) the internal rate of return for the instillation of the geothermal system is found to be 1.6756% which is a very small internal rate of return, and is not likely enough to convince the owner to adopt a geothermal system. If an inflation rate higher than the internal rate of return is used, the system will not be profitable. When an inflation rate of 3% is assumed, the net present value is found to be -$271,412.27

In a colder climate, a geothermal heating system is more likely to be profitable. Pennsylvania had 5968 degree days in the 2008/2009 heating year (U.S. Department of Commerce National Oceanic and Atmospheric Administration: National Enviornmental Satellite, Data, and Information Service 2010). If the same system is sufficient for that environment, it will have an internal rate of return of 3.01%

Conclusion

A geothermal system would represent a significant upfront cost, as well as impact the project schedule. The schedule impacts would result in increased general conditions for Pershing Hill Elementary School which would further increase the upfront costs. Although the geothermal system would provide an annual savings, the internal rate of return is less than 2% and would not be expected to beat inflation. This resulted in an estimated lifecycle cost of -$271,412.27, based on a 3% annual inflation rate. In colder climates, geothermal systems represent a greater annual energy savings, and are more likely to be economical.

Analysis 3: Pre-Fabricated System

Introduction to Analysis

Although Lean Production theory was initially developed for manufacturing, and has been widely accepted in that field, the similarities between craft manufacturing and the construction process make it very applicable to construction (J. Farrar, S. AbouRizk, and X. Mao 2004). Lean Construction is to a great extent an adaptation and implementation of the Lean Production principles within the construction process (S. Bertelsen 2004). Any time, space, or materials used for an activity that does not directly contribute value to the finished product is considered waste (J. Farrar, S. AbouRizk, and X. Mao 2004). The underlying goal of lean production theory is the avoidance, elimination, or reduction of waste (J. Farrar, S. AbouRizk, and X. Mao 2004).

Pre-fabricated systems are typically higher quality due to the ability to construct them in a controlled environment. On-site time can be reduced compared to stick-built construction, and prefabricated masonry may eliminate the need for cold weather construction practices and on-site scaffolding (The Brick Industry Association). The schedule for Pershing Hill Elementary School calls for masonry work to be done on site from the 13th of November 2009 to the 13th of August 2010 (Mitchell Reiners 2009). This encompasses winter, so there would be a need for cold weather construction practices using stick built masonry. Because cold weather methods and the on-site scaffolding do not contribute value to the final product, eliminating them will be considered an elimination of waste.

System Properties

Most pre-fabricated systems have lifting devices built into the panels so that they can be lifted into place by a crane (The Brick Industry Association). For this analysis it will be assumed that the current wall system will be prefabricated in a series of panels that are welded or bolted to the structure. The panels would be constructed off site by the hand-laying method. The hand-laying method is chosen, since the masonry contractor's regular force can serve as the off-site prefabricator. The casting method would not be appropriate for production on this project, as the walls contain an air space. In some cases the structure of the building can be downsized due to the ability of the prefabricated system to span column to column (The Brick Industry Association). An analysis of the structural impacts is beyond the scope of this analysis, and as a result it will be assumed that the structural system remains the same.

Schedule Impacts

Prefabricated masonry panels have a daily output between 500 and 750 square feet per crew according to RS Means (Appendix E). For this analysis a daily output of 500 square feet will be assumed. Traditional (stick build) masonry has a daily output of 240 square feet per crew per day, according to RS Means. For this analysis it will be assumed that the entire façade will be replaced with a pre-fabricated system.

When the durations are adjusted for the pre-fabricated System (Appendix I) the final end date of the project moves up by 2 days. The end date for the masonry contractor moves from July 21st to July 2nd. Although there is a significant reduction in time for the masonry subcontract, there is a minimal effect on the final end date because not all masonry activities are on the critical path and when the critical masonry activities are shortened other activities become critical.

Constructability Analysis

Adopting a pre-fabricated system will have several impacts on building construction. These impacts include: the need for a crane, the elimination if scaffolding and cold weather construction methods, and the need for storage of the masonry panels.

The use of pre-fabricated panels would require use of a crane for erection. There is already a crane on site for steel erection, but there are three different crane locations based on which area the steel is working on. While the masonry contractor is scheduled to work on area A starting November 13th 2009 the steel contractor doesn't start until January 2010. This means that the crane would need to be brought on site earlier, which would result in additional expenses. Both trades work on area B at the same time, which means an additional crane would not be needed (since both trades are in the same area) but coordination would be needed between the trades in order to "share" the crane. The masonry contractor is scheduled to finish area B in June, while the steel contractor isn't scheduled to finish area B until July. This means that the masonry contractor begins work on area C a month earlier, during which time two cranes would be needed on site (because of the different areas). The masonry contractor is scheduled to finish in area C two weeks before the steel contractor. Renting a crane for the additional three months would represent a significant cost to the owner.

The masonry work is scheduled to be done over winter. This would require cold weather methods of construction for the stick built masonry. Pre-fabricated systems do not require additional cold weather methods (The Brick Industry Association). This would make construction easier during the winter, and the workers are likely to be more productive. Pre-fabrication will also eliminate the need for scaffolding (The Brick Industry Association). This would free up the area around the building during construction, and eliminate safety problems associated with objects falling from scaffolding.

Storage space will be required for panels that are delivered before erection. This could take the space of the scaffolding on the existing site plans. However, when proper schedule of delivery is maintained, the panels can be erected as they are delivered, eliminating any need for panel storage at the site (The Brick Industry Association). If delivery is timed to eliminate the need for storage at the site, it would free up a large portion of the site currently used by scaffolding.

Conclusion

Preconstruction would have a favorable impact to the project schedule, but would have mixed effects on the constructability of the project. Because the durations of the masonry and the structural steel do not line up perfectly, an additional crane would be needed for three months of the project. During the other portion of the masonry duration, coordination between the steel erector and masonry contractor would need to be increased in order to share the crane. Prefabrication would provide some benefits to construction, by eliminating the need for scaffolding and cold weather construction techniques.

Analysis 4: LEED Certification

Introduction to Analysis

It was discussed at the PACE Roundtable conference that schools are moving towards LEED certification. There are many benefits to LEED certification. Green schools are healthy for occupants and the environment, as well as productive learning environments (U.S. Green Building Council). LEED certification can often be achieved for little or no additional cost (James D. Qualk and Paul McCown 2009). This analysis will look at the additional costs that would be associated with perusing LEED certification for Pershing Hill Elementary School.

Requirements Currently Met

Pershing Hill Elementary would face the requirements of LEED for schools. This requires certain prerequisites be met among with at least 40 of a possible 110 points accumulated for LEED Certification. Current prerequisites met include: construction activity pollution prevention, environmental site assessment, fundamental refrigerant management, storage and collection of recyclables, minimum air quality performance, and environmental tobacco smoke control.

Sustainable Sites Prerequisite 1: Construction Activity Pollution Prevention requires the creation and implementation of an erosion and sediment control plan for all construction activities. This requirement would be met by the sediment control plan that was already required by Anne Arundel County.

Sustainable Sites Prerequisite 2: Environmental Site Assessment requires an environmental site assessment, and for any contamination to be removed. A portion of the site was previously used as a burn pit, which was discovered and removed during site excavation.

Energy and Atmosphere Prerequisite 3: Fundamental Refrigerant Management requires zero use of chlorofluorocarbons. The building design currently meets this requirement.

Materials and Resources Prerequisite 1: Storage and Collection of Recyclables requires a dedicated area for the collection and storage of recyclables, to reduce waste generated by building occupants. Anne Arundel County Public Schools currently has a recycling program that meets these requirements.

Indoor Environmental Quality Prerequisite 1: Minimum Air Quality Performance requires the minimum requirements of sections 4 through 7 of ASHRAE standard 62.1-2007, Ventilation for Acceptable Indoor Air Quality be met. Although a full analysis of the mechanical system is beyond the scope of this analysis, it is assumed that it was designed to meet ASHRAE standards.

Indoor Environmental Quality Prerequisite 2: Environmental Tobacco Smoke Control requires the owner to prohibit smoking within the building and within 25 feet from entries, outdoor air intakes, and operable windows. Anne Arundel County Public Schools already prohibits smoking in these areas.

In addition to the prerequisites, at least 40 points must be earned to achieve LEED Certification. The building, as designed, and with the current construction practices would only achieve 20 points (Appendix J). This means that 20 additional points must be achieved for LEED Certification.

Additional Requirements

Additional Requirements that would need to be met to achieve LEED Certification include prerequisites and additional points. Current prerequisites not met include: water use reduction, fundamental commissioning of building energy systems, minimum energy performance, and minimum acoustical performance.

Water Efficiency Prerequisite 1: Water Use Reduction requires that strategies be used such that the building uses 20% less water than a baseline building. Potential strategies to achieve this point include the use of WaterSense-Certified fixtures, high-efficiency fixtures, dry fixtures, and alternate on site sources of water (U.S. Green Building Council 2008). The current specified water closets, urinals and faucets use the same amount of water as the baseline building (only water closets, urinals, faucets, and spray valves are counted towards this credit)

Energy and Atmosphere Prerequisite 1: Fundamental Commissioning of Building Energy Systems requires commissioning to ensure the building's energy related systems are functioning as designed. The current project schedule does not include commissioning.

Energy and Atmosphere Prerequisite 2: Minimum Energy Performance has three possible options in order to satisfy the requirement. Option 1 involves energy calculations using a computer simulation model for the entire project. Although it is possible the building could achieve this prerequisite under this option, the analysis involved is beyond the scope of this analysis. The other options involve compliance with prescriptive design guides, and would need to be implemented during the design phase of the project.

Indoor Environmental Quality Prerequisite 3: Minimum Acoustical Performance requires a maximum background noise from HVAC systems of 45 dBA and that classrooms include sufficient finishes for compliance with ANSI Standard S12.20-2002. It is assumed for this analysis that ANSI Standards are met during design. This prerequisite further requires that the ceiling area in core learning spaces of less than 20,000 cubic feet is finished with a material that has a noise reduction coefficient (NRC) of 0.7 or higher. The current acoustical ceiling specifications only require a NRC of 0.55 or higher.

There are a variety of ways the additional 20 points could be met. A green roof (as studied in analysis 1) would provide 2 additional points (for storm water design and heat island effect) as well as an innovation and design process additional credit for exemplary performance under SS credit 7.2 if 100% of the roof were green. Given the additional structural impacts of the green roof (as well as increased general conditions for the roofing contractor's additional time) this likely is not the most cost efficient method towards LEED Certification.

A Geothermal system (as studied in analysis 2) could potentially provide 7 credits under energy and atmosphere credit 2, on-site renewable energy, and potentially three additional credits under Innovation in Design for exemplary performance. This would result in an additional 10 credits. However, there is a large upfront cost with the geothermal system, and analysis 2 found that there was a life cycle cost as well.

There are other ways to achieve LEED credits not previously analyzed in this report. By reducing parking to the minimum required by the building code, and providing preferential parking for energy efficient vehicles, it is possible to achieve four credits for alternative transportation. A construction waste management plan that diverts 50% of materials from landfills (e.g. to be recycled) provides another credit. Some points can be achieved through buying certain materials. Providing at least 35% of the building's electrical need through "green power" sources for at least two years following construction can earn two additional points, and additional points can be achieved through using salvaged or recycled building materials. If 5% of the building materials are salvaged or reused one point is awarded, and if 10% of the building materials are salvaged two points are awarded. Because the first phase of the project includes demolition of the existing school, this project has the opportunity to salvage certain materials from it.

A final credit is awarded to schools for using the school as a teaching school. To do this, a curriculum based on the sustainable features must be integrated into the school's curriculum and the curriculum must be implemented within 10 months of LEED certification. The curriculum must include at least 10 hours of classroom instruction per student per year.

If the additional credits for the geothermal system, parking plan, construction waste management, green power, use of salvaged materials, and using the school as a teaching school are awarded, it is likely the school would be LEED certified.

Additional Costs

Additional costs are associated with some of the LEED certification prerequisites and additional credits.

The water use reduction prerequisite could be met through the use of water efficient and dry fixtures. The average cost of a urinal is $625 (RSMeans 2008) but the average cost of a waterless urinal is $470 (RS Means 2009) although there are not enough urinals on this project for this to represent a significant savings (only 2 as opposed to 55 water closets). Low flow toilets costs are similar to conventional fixtures in initial cost, although there is a wide range in cost, meaning this prerequisite could be perused at little to no additional cost.

Additional initial cost is associated with the commissioning of the building systems, although commissioning can lower operating costs (U.S. Green Building Council 2008). The costs of commissioning vary from 0.5 to 0.75% of the project cost (RSMeans 2008) which would result in an additional cost of between $66,558 and $99,838.

The minimum acoustical performance prerequisite would require replacing the acoustical ceiling tiles with ones that have a NRC of 0.7 or higher in the classrooms. The current tiles, not including the suspension system, have an average cost of $1.59 per square foot (RSMeans 2008). Cirrus Tile and Lay-In by Armstrong meets this requirement (Armstrong) and costs $120.46 per box (Denver Ceilings). With 12 2x2 tiles per box (same size as current tiles) this breaks down to a cost of $2.51 per square foot. This is a difference of 92 cents per square foot, which is approximately $30,636 when applied to all 37 classroom areas.

A full cost analysis of the geothermal system was provided in analysis 2. It was found to have an upfront cost of $726,023 and a lifecycle cost of $271,412.

The parking plan would require reducing the amount of parking area, and providing preferential parking for energy efficient vehicles. Preferential parking can be provided at minimal to no additional cost. While reducing the amount of parking would provide a savings to the owner, the amount of parking would change only slightly, so the savings would be minimal.

Construction waste management would involve segregating recyclables from other trash. The most common method of this involves a separate dumpster for recyclables. At a cost of $775 per week, this represents an additional cost of $68,200 over the course of the project.

Green energy can be purchased at a cost of 10.8 cents per kWh for 100% green energy at this project's location (Clean Currents). This is actually cheaper than the average cost for electric energy of 11.14 cents per kWh for commercial buildings in the state of Maryland (U.S. Energy Information Administration). This suggests that the owner would want to switch to green energy even if they chose not to pursue LEED certification. The savings will not offset the additional costs of pursuing LEED certification, because the option to purchase green energy is still available if the owner chooses not to pursue LEED certification.

The demolition of the existing school gives the owner the opportunity to reuse a portion of the building materials from the existing school. To get a single credit, 5% of the building material must be reused. This would represent a significant savings to the owner but this savings will not offset the additional costs of pursuing LEED certification, because the option to reuse material from the existing building is still available if the owner chooses not to pursue LEED certification.

Using the school as a teaching tool would not require additional facilities or material costs, but would require modifying the curriculum. While there is not a direct cost associated with this option, it requires participation from the school board, additional training for the teachers in the green features of the building, and has the potential to be politically difficult to implement.

These strategies would result in an additional initial cost between $891,417 and $924,697 to pursue LEED certification. When these numbers are averaged, it represents 6.8% of the current construction costs. It should be noted that $726,023 is the additional cost estimated for the geothermal system in analysis 2. When the life cycle cost of the geothermal system is used instead, the cost of pursuing LEED certification falls to between $436,806 and $470,086. When these numbers are averaged, it represents 3.4% of the current construction costs.

Conclusion

Perusing LEED Certification would result in additional cost for Pershing Hill Elementary School. Although there would be significant initial costs, there would be lower lifecycle costs. The additional initial costs of 6.8% are much higher than the literature suggested. While green schools averaged only a 1.7% premium, the premium varied between projects and one school faced a 6.3% premium (Greg Kats 2006). Additional costs are associated with starting perusing LEED certification later in the project lifecycle.

In addition, most studies only look at the additional costs of LEED certified projects when compared to the cost of non certified projects. When performing this analysis there were several options (e.g. reducing the size of the parking lot) which would have reduced project cost. These were not factored in to offsetting the premium for this analysis though, as they could be applied even if the project did not pursue LEED certification. It is likely these options would have been perused if the project sought to achieve LEED certification, which would have offset a portion of the initial costs.

MAE Summary

Research methods learned in AE 597K (Research Methods in Architectural Engineering) will be used to perform research on green roofs, geothermal systems, and precast systems, as identified in analysis activities 1, 2, and 3. A large portion of information on green roofs and green roof properties was taken from the class notes and lectures in AE 542 (Building Enclosure Science and Design). When assessing schedule impacts, information from CE 533 (Construction Productivity and Performance Analysis) was used to determine the optimal way to accelerate the schedule as to avoid a decrease in productivity associated with long durations of overtime, and overcrowding. .

The H.A.M tool used to aid in determining the heating loads for the geothermal system in Analysis 2 was introduced in used in AE 542 in the analysis of wall systems. The proforma used to determine the internal rate of return of the geothermal system was introduced in AE 572 (Project Development and Delivery Planning) to assess the profitability of projects and was modified to find the internal rate of return of the geothermal system.

Bibliography

Armstrong. Cirrus Tile & Lay-In by Armstrong. http://www.armstrong.com/commceilingsna/ceiling_family_detail.jsp?productLineId=2.0&criteria=acoustics.

Clean Currents. Clean Currents Home – A leading wind and solar power supplier and installer for maryland, virginia and washington dc - C Green Overview. http://www.cleancurrents.com/index.php/C-Green-Overview.

Denver Ceilings. Armstrong Ceiling Tiles. http://www.denver-ceilings.com/Armstrong_ceiling_tiles.html.

Dr. Richard A. Behr. 2010. Design of Sustainable Roof Systems: Benefits, Constructability, and Design of Green Roofs presented at the AE 542, February 17, 373 Willard.

DSIRE. DSIRE: Database of State Incentives for Renewables & Efficiency. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=MD21F&re=1&ee=1.

Foreman University. 2009. Geothermal Heat Exchangers: Module FPCM. via email, December 7.

Greg Kats. 2006. Greening America's Schools: Costs and Benefits. http://www.chartwell.org/UserFiles/File/Greening_America_s_Schools.pdf.

J. Farrar, S. AbouRizk, and X. Mao. 2004. Generic Implementation of Lean Concepts in Simulation Models. *Lean Construction Journal* 1, no. 1 (October): 1-23.

James D. Qualk, and Paul McCown. 2009. Busting the Myth that Green Costs More Green - Strategic Planning for Energy and the Environment. *Strategic Planning for Energy and the Enviornment* 28, no. 4 (April): 36-48.

Jeroen Mentensa, Dirk Raesa and Martin Hermy. 2005. ScienceDirect - Landscape and Urban Planning : Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? May 13. http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V91-4G5BJ9W-2&_user=209810&_coverDate=08%2F30%2F2006&_rdoc=1&_fmt=high&_orig=search&_sort=d&_docanchor=&view=c&_acct=C000014439&_version=1&_urlVersion=0&_userid=209810&md5=d9432c9ec17b225d36c09a5352b0d387.

Karl Ochsner. 2008. *Geothermal Heat Pumps: A Guide for Planning and Installing*. Sterling, VA: Earthscan.

Mitchell Reiners. 2009. Technical Report 2: Cost and Schedule Analysis. October 29. http://www.engr.psu.edu/ae/thesis/portfolios/2010/mrr5025/Tech%202/Tech%202.pdf.

National Propane Gas Association. DOE Energy Costs - National Propane Gas Association. http://www.npga.org/i4a/pages/index.cfm?pageid=914.

RSMeans. 2008. *RSMeans: Building Construction Cost Data*. 67th ed. Kingston, MA: R.S. Means Company, Inc.: Construction Publishers & Consultants.

S. Bertelsen. 2004. Lean Construction: Where are we and how to proceed? *Lean Construction Journal* 1, no. 1 (October): 46-69.

Susan K. Weiler, Katrin Scholz-Barth. 2009. *Green Roof Systems: A Guide to the Planning, Design, and Construction of Landscapes over Structure*. Hoboken, New Jersey: John Wiley & Sons, Inc.

The Brick Industry Association. Technical Notes 40 - Prefabricated Brick Masonry. http://www.gobrick.com/BIA/technotes/t40.htm.

U.S. Department of Commerce National Oceanic and Atmospheric Administration: National Enviornmental Satellite, Data, and Information Service. 2010. Monthly, State, Regional and National Heating Degree Days. National Climatic Data Center, March.

U.S. Department of Energy. Guide to Tribal Energy Development: Geothermal Resources. http://www1.eere.energy.gov/tribalenergy/guide/geothermal_resources.html.

U.S. Energy Information Administration. Energy Information Administration (EIA) | State/Territory Energy Profiles | Energy Data, Information, and Maps. http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=MD.

U.S. Green Building Council. USGBC: LEED for Schools. http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1586.

———. 2008. LEED 2009 for Schools: New Construction and Major Renovations. U.S. Green Building Council, November. http://www.usgbc.org/ShowFile.aspx?DocumentID=5547.

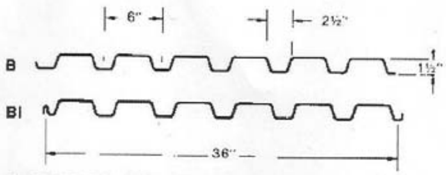
Appendix A

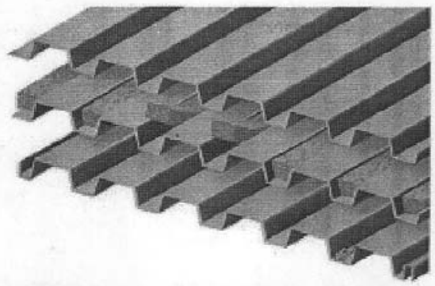
Vulcraft Catalog

VULCRAFT

1.5 B, BI, BA, BIA

Maximum Sheet Length 42'-0 — ICBO Approved (No.3415)
Factory Mutual Approved
Deck type & gauge — Max. deck span
1.5B22, 1.5BI22.................. 6'-0"
1.5B20, 1.5BI20.................. 6'-6"
1.5B18, 1.5BI18.................. 7'-5"
FM Approvals No. 0C8A7.AM & 0G1A4.AM





ROOF

SECTION PROPERTIES

Deck Type	Design Thick.	Weight (PSF) Ptd.	Weight (PSF) Galv.	I in^4/ft	Sp in^3/ft	Sn in^3/ft	Fy KSI
B24	0.0239	1.36	1.46	0.121	0.120	0.131	60
B22	0.0295	1.68	1.78	0.169	0.186	0.192	33
B21	0.0329	1.87	1.97	0.192	0.213	0.221	33
B20	0.0358	2.04	2.14	0.212	0.234	0.247	33
B19	0.0418	2.39	2.49	0.253	0.277	0.289	33
B18	0.0474	2.72	2.82	0.292	0.318	0.327	33
B16	0.0598	3.44	3.54	0.373	0.408	0.411	33

ACOUSTICAL INFORMATION

Deck Type	Absorption Coefficient 125	250	500	1000	2000	4000	Noise Reduction Coefficient*
1.5BA, 1.5BIA	.11	.20	.63	1.04	.66	.36	.65

* Source: Riverbank Acoustical Laboratories — RAL™ A94–185.
Test was conducted with 1.5 inches of 1.65 pcf fiberglass insulation on 3 inch EPS Plaza deck for the SDI.

Type B (wide rib) deck provides excellent structural load carrying capacity per pound of steel utilized, and its nestable design eliminates the need for die-set ends.

1" or more rigid insulation is required for Type B deck.

Acoustical deck (Type BA, BIA) is particularly suitable in structures such as auditoriums, schools, and theatres where sound control is desirable. Acoustic perforations are located in the vertical webs where the load carrying properties are negligibly affected (less than 5%).

Inert, non-organic glass fiber sound absorbing batts are placed in the rib openings to absorb up to 65% of the sound striking the deck.

Batts are field installed and may require separation.

VERTICAL LOADS FOR TYPE 1.5B

No. of Spans	Deck Type	Max. SDI Const. Span	Allowable Total (Dead + Live) Uniform Load (PSF) Span (ft.-in.) C. to C. of Support 5'-0	5'-6	6'-0	6'-6	7'-0	7'-6	8'-0	8'-6	9'-0	9'-6	10'-0
1	B 24	4'-8	66	52	42	36	30	27	24	21	20		
	B 22	5'-7	91	71	57	47	40	34	30	27	24	22	20
	B 21	6'-0	104	81	64	53	44	38	33	29	26	24	22
	B 20	6'-5	115	89	71	58	48	41	36	31	28	25	23
	B 19	7'-1	139	107	85	69	57	48	41	36	32	29	26
	B 18	7'-8	162	124	98	79	65	55	47	41	36	32	29
	B 16	8'-8	206	157	123	99	81	68	58	50	44	39	34
2	B 24	5'-10	126	104	87	74	64	55	47	41	36	32	29
	B 22	6'-11	102	85	71	61	52	46	40	35	32	28	26
	B 21	7'-4	118	97	82	70	60	52	46	41	36	33	29
	B 20	7'-9	132	109	91	78	67	59	51	46	41	36	33
	B 19	8'-5	154	127	107	91	79	69	60	53	48	43	39
	B 18	9'-1	174	144	121	103	89	78	68	60	54	48	44
	B 16	10'-3	219	181	152	130	112	97	85	76	68	61	55
3	B 24	5'-10	[illegible]	100	79	65	54	45	39	[illegible]	31	[illegible]	[illegible]
	B 22	6'-11	128	106	89	76	65	57	50	44	39	34	31
	B 21	7'-4	147	122	102	87	75	65	56	49	42	38	34
	B 20	7'-9	165	136	114	97	84	72	61	53	46	41	36
	B 19	8'-5	193	159	134	114	98	84	71	61	53	47	41
	B 18	9'-1	218	180	151	129	111	96	81	69	60	52	46
	B 16	10'-3	274	226	190	162	140	119	100	85	73	64	56

Notes: 1. Load tables are calculated using sectional properties based on the steel design thickness shown in the Steel Deck Institute (SDI) Design Manual.
2. Loads shown in the shaded areas are governed by the live load deflection not in excess of 1/240 of the span. A dead load of 10 PSF has been included.
3 ** Acoustical Deck is not covered under Factory Mutual

3

Appendix B

LRFD Tables

LRFD

STANDARD LOAD TABLE FOR KCS OPEN WEB STEEL JOISTS
Based on a 50 ksi Maximum Yield Strength

JOIST DESIGNATION	DEPTH (inches)	MOMENT CAPACITY (inch-kips)	SHEAR CAPACITY* (lbs)	APPROX. WEIGHT** (lbs/ft)	GROSS MOMENT OF INERTIA (in.^{4})	BRIDGING TABLE SECTION NUMBER
10KCS1	10	258	3000	6.0	29	1
10KCS2	10	337	3750	7.5	37	1
10KCS3	10	444	4500	10.0	47	1
12KCS1	12	313	3600	6.0	43	3
12KCS2	12	411	4500	8.0	55	5
12KCS3	12	543	5250	10.0	71	5
14KCS1	14	370	4350	6.5	59	4
14KCS2	14	486	5100	8.0	77	6
14KCS3	14	642	5850	10.0	99	6
16KCS2	16	523	6000	8.5	99	6
16KCS3	16	705	7200	10.5	128	9
16KCS4	16	1080	7950	14.5	192	9
16KCS5	16	1401	8700	18.0	245	9
18KCS2	18	592	7050	9.0	127	6
18KCS3	18	798	7800	11.0	164	9
18KCS4	18	1225	8550	15.0	247	10
18KCS5	18	1593	9300	18.5	316	10
20KCS2	20	663	7800	9.5	159	6
20KCS3	20	892	9000	11.5	205	9
20KCS4	20	1371	11850	16.5	308	10
20KCS5	20	1786	12600	20.0	396	10
22KCS2	22	732	8850	10.0	194	6
22KCS3	22	987	9900	12.5	251	9
22KCS4	22	1518	11850	16.5	377	11
22KCS5	22	1978	12900	20.5	485	11
24KCS2	24	801	9450	10.0	232	6
24KCS3	24	1080	10800	12.5	301	9
24KCS4	24	1662	12600	16.5	453	12
24KCS5	24	2172	13350	20.5	584	12
26KCS2	26	870	9900	10.0	274	6
26KCS3	26	1174	11700	12.5	355	9
26KCS4	26	1809	12750	16.5	536	12
26KCS5	26	2364	13800	20.5	691	12
28KCS2	28	939	10350	10.5	320	6
28KCS3	28	1269	12000	12.5	414	9
28KCS4	28	1954	12750	16.5	626	12
28KCS5	28	2556	13800	20.5	808	12
30KCS3	30	1362	12000	13.0	478	9
30KCS4	30	2100	12750	16.5	722	12
30KCS5	30	2749	13800	21.0	934	12

*MAXIMUM UNIFORMLY DISTRIBUTED LOAD CAPACITY IS 825 PLF AND SINGLE CONCENTRATED LOAD CANNOT EXCEED SHEAR CAPACITY
**DOES NOT INCLUDE ACCESSORIES

32

LRFD

ECONOMY TABLE FOR OPEN WEB STEEL JOISTS, K-SERIES
Based on a 50 ksi Maximum Yield Strength - Loads Shown in Pounds per Linear Foot (plf)

Joist Designation	14K6	18K5	22K4	16K6	20K5	24K4	18K6	16K7	22K5	20K6	18K7	22K6	20K7	24K5	22K7	24K6
Depth (In.)	14	18	22	16	20	24	18	16	22	20	18	22	20	24	22	24
Approx. Wt. (lbs/ft.)	7.7	7.7	8.0	8.1	8.2	8.4	8.5	8.6	8.8	8.9	9.0	9.2	9.3	9.3	9.7	9.7
Span (ft.)																
14	825 550															
15	825 507															
16	825 467			825 550				825 550								
17	825 443			825 526				825 526								
18	825 408	825 550		825 490			825 550	825 490			825 550					
19	825 383	825 523		825 455			825 523	825 455			825 523					
20	787 347	825 490		825 426	825 550		825 490	825 426		825 550	825 490		825 550			
21	712 299	825 460		822 405	825 520		825 460	825 406		825 520	825 460		825 520			
22	648 259	777 414	825 548	747 351	825 490		825 438	825 385	825 548	825 490	825 438	825 548	825 490		825 548	
23	592 226	709 362	777 491	682 307	793 451		774 393	760 339	825 518	825 468	825 418	825 518	825 468		825 518	
24	543 199	651 318	712 431	627 269	727 396	780 516	709 345	697 298	804 483	792 430	789 382	825 495	825 448	825 544	825 495	825 544
25	501 175	600 281	657 381	576 238	669 350	718 456	652 305	642 263	739 427	729 380	727 337	805 464	811 421	810 511	825 474	825 520
26	462 156	553 249	606 338	532 211	618 310	663 405	603 271	592 233	682 379	673 337	672 299	744 411	750 373	748 453	825 454	814 493
27	427 139	513 222	561 301	493 188	573 277	615 361	558 241	549 208	633 337	624 301	622 267	688 367	694 333	693 404	768 406	754 439
28	397 124	477 199	522 270	459 168	532 248	571 323	519 216	510 186	588 302	579 269	577 239	640 328	645 298	643 362	712 364	700 393
29		444 179	486 242	427 151	495 223	531 290	483 194	475 167	547 272	540 242	538 215	597 295	601 268	600 325	664 327	652 354
30		414 161	453 219	399 137	462 201	496 262	451 175	444 151	511 245	504 218	502 194	556 266	561 242	559 293	619 295	609 319
31		387 146	424 198	373 124	433 182	465 237	421 158	415 137	478 222	471 198	469 175	520 241	525 219	523 266	580 267	570 289
32		363 132	397 180	349 112	406 165	435 215	396 144	388 124	448 201	442 179	441 159	489 219	492 199	490 241	544 242	535 262
33		342 121	373 164		254 150	273 196	248 131		421 183	415 163	414 145	459 199	463 181	462 220	511 221	502 239
34		321 110	352 149		358 137	257 179	233 120		397 167	391 149	390 132	432 182	435 165	435 201	481 202	472 218
35		303 101	331 137		339 126	363 164	330 110		373 153	369 137	367 121	408 167	411 151	409 184	454 185	445 200
36		286 92	313 126		319 115	343 150	312 101		354 141	348 125	348 111	385 153	388 139	387 169	429 169	421 183
37			297 116		303 106	324 138			334 130	330 115		364 141	367 128	366 155	406 156	399 169
38			280 107		286 98	307 128			316 119	312 106		345 130	348 118	346 143	384 144	378 156
39			267 98		271 90	292 118			300 110	297 98		327 120	330 109	328 132	364 133	358 144
40			253 91		258 84	277 109			285 102	282 91		310 111	313 101	312 122	346 123	340 133
41			241 85			264 101			271 95			295 103		297 114	330 114	324 124
42			229 79			252 94			259 88			282 96		283 106	313 106	309 115
43			219 73			240 88			247 82			268 89		270 98	300 99	294 107
44			208 68			229 82			235 76			256 83		258 92	286 92	280 100
45						219 76								246 86		268 93
46						208 71								235 80		256 87
47						199 67								225 75		246 82
48						192 63								216 70		235 77

C-3

Appendix C

Flexural Design Tables

10

Table 3-2 (continued) W Shapes Selection by Z_x

Z_x — F_y = 50 ksi

Shape	Z_x in.³	M_{px}/Ω_b kip-ft ASD	$\phi_b M_{px}$ kip-ft LRFD	M_{rx}/Ω_b kip-ft ASD	$\phi_b M_{rx}$ kip-ft LRFD	BF kips ASD	BF kips LRFD	L_p ft	L_r ft	I_x in.⁴	V_{nx}/Ω_v kips ASD	$\phi_v V_{nx}$ kips LRFD
W24×84	224	559	840	342	515	16.2	24.3	6.89	20.3	2370	227	340
W21×93	221	551	829	335	504	14.6	21.9	6.50	21.3	2070	251	376
W12×136	214	534	803	325	488	4.01	6.03	11.2	63.3	1240	212	318
W14×120	212	529	795	332	499	5.09	7.64	13.2	52.0	1380	171	256
W18×97	211	526	791	328	494	9.45	14.2	9.36	30.3	1750	199	298
W24×76	200	499	750	307	462	15.0	22.5	6.78	19.6	2100	210	316
W16×100	198	494	743	306	459	7.90	11.9	8.87	32.7	1490	199	298
W21×83	196	489	735	299	449	13.8	20.8	6.46	20.2	1830	221	331
W14×109	192	479	720	302	454	5.02	7.54	13.2	48.4	1240	150	226
W18×86	186	464	698	290	436	9.04	13.6	9.29	28.5	1070	177	265
W12×120	186	464	698	285	428	3.95	5.93	11.1	56.5	1530	186	279
W24×68	177	442	664	269	404	14.1	21.2	6.61	18.8	1830	197	295
W16×89	175	437	656	271	407	7.74	11.6	8.80	30.2	1300	176	264
W14×99[f]	173	430	646	274	412	4.89	7.35	13.5	45.3	1110	137	206
W21×73	172	429	645	264	396	12.9	19.4	6.39	19.2	1600	193	290
W12×106	164	409	615	253	381	3.93	5.90	11.0	50.7	933	157	236
W18×76	163	407	611	255	383	8.49	12.8	9.22	27.1	1330	155	232
W21×68	160	399	600	245	368	12.5	18.8	6.36	18.7	1480	182	273
W14×90[f]	157	382	573	250	375	4.80	7.22	15.2	42.6	999	123	185
W24×62	153	382	574	229	344	16.0	24.1	4.87	14.4	1550	204	306
W16×77	150	374	563	234	352	7.34	11.0	8.72	27.8	1110	150	225
W12×96	147	367	551	229	344	3.87	5.81	10.9	46.6	833	140	210
W10×112	147	367	551	220	331	2.68	4.02	9.47	64.3	716	172	257
W18×71	146	364	548	222	333	10.5	15.7	6.00	19.6	1170	183	274
W21×62	144	359	540	222	333	11.6	17.4	6.25	18.1	1330	168	252
W14×82	139	347	521	215	323	5.43	8.16	8.76	33.1	881	146	219
W24×55[v]	134	334	503	199	299	14.8	22.2	4.73	13.9	1350	167	251
W18×65	133	332	499	204	307	9.92	14.9	5.97	18.8	1070	165	248
W12×87	132	329	496	206	310	3.84	5.76	10.8	43.0	740	129	194
W16×67	130	324	488	204	307	6.91	10.4	8.69	26.1	954	129	194
W10×100	130	324	488	196	294	2.66	4.01	9.36	57.7	623	151	226
W21×57	129	322	484	194	291	13.4	20.1	4.77	14.3	1170	171	256

ASD	LRFD
$\Omega_b = 1.67$ $\Omega_v = 1.50$	$\phi_b = 0.90$ $\phi_v = 1.00$

[f] Shape exceeds compact limit for flexure with $F_y = 50$ ksi.
[v] Shape does not meet the h/t_w limit for shear in Specification Section G2.1a with $F_y = 50$ ksi, $\Omega_v = 1.67$, $\phi_v = 0.90$.

Table 3-2 (continued) W Shapes Selection by Z_x

F_y = 50 ksi — Z_x

Shape	Z_x in.³	M_{px}/Ω_b kip-ft ASD	$\phi_b M_{px}$ kip-ft LRFD	M_{rx}/Ω_b kip-ft ASD	$\phi_b M_{rx}$ kip-ft LRFD	BF kips ASD	BF kips LRFD	L_p ft	L_r ft	I_x in.⁴	V_{nx}/Ω_v kips ASD	$\phi_v V_{nx}$ kips LRFD
W30×116	378	943	1420	575	864	24.7	37.2	7.74	22.6	4930	339	509
W21×147	373	931	1400	575	864	13.8	20.7	10.4	36.3	3630	318	476
W24×131	370	923	1390	575	864	16.3	24.5	10.5	31.9	4020	296	444
W18×158	356	888	1340	541	814	10.5	15.7	9.68	42.8	3060	319	479
W14×193	355	886	1330	541	814	5.27	7.92	14.3	79.7	2400	276	413
W12×210	348	868	1310	510	767	4.24	6.38	11.6	96.0	2140	347	521
W30×108	346	863	1300	522	785	23.7	35.6	7.59	22.0	4470	325	488
W27×114	343	856	1290	522	785	21.7	32.6	7.70	23.1	4080	311	467
W21×132	333	831	1250	515	774	13.3	20.0	10.3	34.1	3220	284	426
W24×117	327	816	1230	508	764	15.3	23.1	10.4	30.4	3540	267	400
W18×143	322	803	1210	493	740	10.4	15.6	9.61	39.6	2750	285	427
W14×176	320	798	1200	491	738	5.22	7.84	14.2	73.2	2140	253	379
W30×99	312	778	1170	470	706	22.2	33.3	7.42	21.4	3990	308	463
W12×190	311	776	1170	459	690	4.18	6.28	11.5	87.3	1890	305	457
W21×122	307	766	1150	477	717	12.9	19.4	10.3	32.7	2960	260	390
W27×102	305	761	1140	466	701	20.2	30.3	7.59	22.2	3620	279	419
W18×130	290	724	1090	447	672	10.2	15.3	9.54	36.7	2460	258	387
W24×104	289	721	1080	451	677	14.3	21.5	10.3	29.2	3100	241	361
W14×159	287	716	1080	444	667	5.18	7.79	14.1	66.7	1900	223	335
W30×90[v]	283	706	1060	428	643	20.5	30.9	7.38	20.9	3610	249	375
W24×103	280	699	1050	428	643	18.2	27.4	7.03	21.9	3000	270	405
W21×111	279	696	1050	435	654	12.4	18.7	10.2	31.3	2670	237	355
W27×94	278	694	1040	424	638	19.1	28.8	7.49	21.6	3270	264	396
W12×170	275	686	1030	410	617	4.11	6.18	11.4	78.5	1650	269	404
W18×119	262	654	983	403	606	10.1	15.2	9.50	34.3	2190	249	373
W14×145	260	649	975	405	609	5.11	7.68	14.1	61.7	1710	201	302
W24×94	254	634	953	388	583	17.3	26.0	6.99	21.2	2700	250	376
W21×101	253	631	949	396	596	11.8	17.7	10.2	30.1	2420	214	320
W27×84	244	609	915	372	559	17.6	26.4	7.31	20.8	2850	246	369
W12×152	243	606	911	365	549	4.07	6.11	11.3	70.6	1430	239	358
W14×132	234	584	878	365	549	5.13	7.70	13.3	56.0	1530	189	284
W18×106	230	574	863	356	538	9.70	14.6	9.40	31.8	1910	221	332

ASD	LRFD
$\Omega_b = 1.67$ $\Omega_v = 1.50$	$\phi_b = 0.90$ $\phi_v = 1.00$

[v] Shape does not meet the h/t_w limit for shear in Specification Section G2.1a with $F_y = 50$ ksi, $\Omega_v = 1.67$, $\phi_v = 0.90$.

10

Table 3–2 (continued)
W Shapes
Selection by Z_x

$F_y = 50$ ksi

Shape	Z_x in.^{3}	M_{px}/Ω_b kip-ft ASD	$\phi_b M_{px}$ kip-ft LRFD	M_{rx}/Ω_b kip-ft ASD	$\phi_b M_{rx}$ kip-ft LRFD	BF kips ASD	BF kips LRFD	L_p ft	L_r ft	I_x in.^{4}	V_{nx}/Ω_v kips ASD	$\phi_v V_{nx}$ kips LRFD
W30×116	378	943	1420	575	864	24.7	37.2	7.74	22.6	4930	339	509
W21×147	373	931	1400	575	864	13.8	20.7	10.4	36.3	3630	318	476
W24×131	370	923	1390	575	864	16.3	24.5	10.5	31.9	4020	296	444
W18×158	356	888	1340	541	814	10.5	15.7	9.68	42.8	3060	319	479
W14×193	355	886	1330	541	814	5.27	7.92	14.3	79.7	2400	276	413
W12×210	348	868	1310	510	767	4.24	6.38	11.6	96.0	2140	347	521
W30×108	346	863	1300	522	785	23.7	35.6	7.59	22.0	4470	325	488
W27×114	343	856	1290	522	785	21.7	32.6	7.70	23.1	4080	311	467
W21×132	333	831	1250	515	774	13.3	20.0	10.3	34.1	3220	284	426
W24×117	327	816	1230	508	764	15.3	23.1	10.4	30.4	3540	267	400
W18×143	322	803	1210	493	740	10.4	15.6	9.61	39.6	2750	285	427
W14×176	320	798	1200	491	738	5.22	7.84	14.2	73.2	2140	253	379
W30×99	312	778	1170	470	706	22.2	33.3	7.42	21.4	3990	308	463
W12×190	311	776	1170	459	690	4.18	6.28	11.5	87.3	1890	305	457
W21×122	307	766	1150	477	717	12.9	19.4	10.3	32.7	2960	260	390
W27×102	305	761	1140	466	701	20.2	30.3	7.59	22.2	3620	279	419
W18×130	290	724	1090	447	672	10.2	15.3	9.54	36.7	2460	258	387
W24×104	289	721	1080	451	677	14.3	21.5	10.3	29.2	3100	241	361
W14×159	287	716	1080	444	667	5.18	7.79	14.1	66.7	1900	223	335
W30×90[v]	283	706	1060	428	643	20.5	30.9	7.38	20.9	3610	249	375
W24×103	280	699	1050	428	643	18.2	27.4	7.03	21.9	3000	270	405
W21×111	279	696	1050	435	654	12.4	18.7	10.2	31.3	2670	237	355
W27×94	278	694	1040	424	638	19.1	28.8	7.49	21.6	3270	264	396
W12×170	275	686	1030	410	617	4.11	6.18	11.4	78.5	1650	269	404
W18×119	262	654	983	403	606	10.1	15.2	9.50	34.3	2190	249	373
W14×145	260	649	975	405	609	5.11	7.68	14.1	61.7	1710	201	302
W24×94	254	634	953	388	583	17.3	26.0	6.99	21.2	2700	250	376
W21×101	253	631	949	396	596	11.8	17.7	10.2	30.1	2420	214	320
W27×84	244	609	915	372	559	17.6	26.4	7.31	20.8	2850	246	369
W12×152	243	606	911	365	549	4.07	6.11	11.3	70.6	1430	239	358
W14×132	234	584	878	365	549	5.13	7.70	13.3	56.0	1530	189	284
W18×106	230	574	863	356	536	9.70	14.6	9.40	31.8	1910	221	332

ASD	LRFD
$\Omega_b = 1.67$ $\Omega_v = 1.50$	$\phi_b = 0.90$ $\phi_v = 1.00$

[v] Shape does not meet the h/t_w limit for shear in Specification Section G2.1a with $F_y = 50$ ksi, $\Omega_v = 1.67$, $\phi_v = 0.90$.

Table 3–2 (continued)
W Shapes
Selection by Z_x

$F_y = 50$ ksi

Shape	Z_x in.^{3}	M_{px}/Ω_b kip-ft ASD	$\phi_b M_{px}$ kip-ft LRFD	M_{rx}/Ω_b kip-ft ASD	$\phi_b M_{rx}$ kip-ft LRFD	BF kips ASD	BF kips LRFD	L_p ft	L_r ft	I_x in.^{4}	V_{nx}/Ω_v kips ASD	$\phi_v V_{nx}$ kips LRFD
W24×84	224	559	840	342	515	16.2	24.3	6.89	20.3	2370	227	340
W21×93	221	551	829	335	504	14.6	21.9	6.50	21.3	2070	251	376
W12×136	214	534	803	325	488	4.01	6.03	11.2	63.3	1240	212	318
W14×120	212	529	795	332	499	5.09	7.64	13.2	52.0	1380	171	256
W18×97	211	526	791	328	494	9.45	14.2	9.36	30.3	1750	199	298
W24×76	200	499	750	307	462	15.0	22.5	6.78	19.6	2100	210	316
W16×100	198	494	743	306	459	7.90	11.9	8.87	32.7	1490	199	298
W21×83	196	489	735	299	449	13.8	20.8	6.46	20.2	1830	221	331
W14×109	192	479	720	302	454	5.02	7.54	13.2	48.4	1240	150	226
W18×86	186	464	698	290	436	9.04	13.6	9.29	28.5	1070	177	265
W12×120	186	464	698	285	428	3.95	5.93	11.1	56.5	1530	186	279
W24×68	177	442	664	269	404	14.1	21.2	6.61	18.8	1830	197	295
W16×89	175	437	656	271	407	7.74	11.6	8.80	30.2	1300	176	264
W14×99[f]	173	430	646	274	412	4.89	7.35	13.5	45.3	1110	137	206
W21×73	172	429	645	264	396	12.9	19.4	6.39	19.2	1600	193	290
W12×106	164	409	615	253	381	3.93	5.90	11.0	50.7	933	157	236
W18×76	163	407	611	255	383	8.49	12.8	9.22	27.1	1330	155	232
W21×68	160	399	600	245	368	12.5	18.8	6.36	18.7	1480	182	273
W14×90[f]	157	382	573	250	375	4.80	7.22	15.2	42.6	999	123	185
W24×62	153	382	574	229	344	16.0	24.1	4.87	14.4	1550	204	306
W16×77	150	374	563	234	352	7.34	11.0	8.72	27.8	1110	150	225
W12×96	147	367	551	229	344	3.87	5.81	10.9	46.6	833	140	210
W10×112	147	367	551	220	331	2.68	4.02	9.47	64.3	716	172	257
W18×71	146	364	548	222	333	10.6	15.7	6.00	19.6	1170	183	274
W21×62	144	359	540	222	333	11.6	17.4	6.25	18.1	1330	168	252
W14×82	139	347	521	215	323	5.43	8.16	8.76	33.1	881	146	219
W24×55[v]	134	334	503	199	299	14.8	22.2	4.73	13.9	1350	167	251
W18×65	133	332	499	204	307	9.92	14.9	5.97	18.8	1070	165	248
W12×87	132	329	495	206	310	3.84	5.76	10.8	43.0	740	129	194
W16×67	130	324	488	204	307	6.91	10.4	8.69	26.1	954	129	194
W10×100	130	324	488	196	294	2.66	4.01	9.36	57.7	623	151	226
W21×57	129	322	484	194	291	13.4	20.1	4.77	14.3	1170	171	256

ASD	LRFD
$\Omega_b = 1.67$ $\Omega_v = 1.50$	$\phi_b = 0.90$ $\phi_v = 1.00$

[f] Shape exceeds compact limit for flexure with $F_y = 50$ ksi.
[v] Shape does not meet the h/t_w limit for shear in Specification Section G2.1a with $F_y = 50$ ksi, $\Omega_v = 1.67$, $\phi_v = 0.90$.

Appendix D

HSS Tubing Allowable Loads

HSS / Rectangular Structural Steel Tubing

Allowable Concentric Loads in Kips

Fy=50

ERW

Nominal Size	9 x 5						9 x 3				
Wall Thickness	5/8	1/2	3/8	5/16	1/4	3/16	1/2	3/8	5/16	1/4	3/16
Weight Per Foot	50.81	42.05	32.58	27.59	22.42	17.08	35.24	27.48	23.34	19.02	14.53
Design Wall Thickness	0.581	0.465	0.349	0.291	0.233	0.174*	0.465	0.349	0.291	0.233	0.174*
	F_y = 50 ksi										
Effective length KL in feet: 0	420	348	269	228	185	125	292	227	193	157	105
2	406	337	261	221	180	122	275	215	182	149	101
3	398	330	256	217	176	120	263	206	175	143	98
4	388	323	250	212	173	118	250	196	167	137	95
5	378	314	244	207	168	116	235	185	158	130	91
6	366	305	237	201	164	114	218	173	148	122	87
7	354	295	230	195	159	111	200	160	137	113	83
8	341	285	222	189	154	109	180	145	126	104	77
9	327	274	214	182	148	106	158	130	113	94	72
10	312	262	205	174	143	102	135	113	99	84	65
11	296	249	196	167	136	99	112	95	85	72	56
12	280	236	186	159	130	95	94	80	71	61	48
13	263	222	176	150	123	91	80	68	61	52	41
14	245	208	166	141	116	87	69	59	52	45	35
15	226	193	154	132	109	82	60	51	46	39	31
16	206	177	143	123	101	77	53	45	40	34	27
17	185	161	131	112	93	72	47	40	35	30	24
18	165	144	118	102	85	66	42	36	32	27	21
19	148	129	106	92	77	59	38	32	28	24	19
20	134	117	96	83	69	53	=	29	26	22	17
21	121	106	87	75	63	48		=	=	20	16
22	111	96	79	68	57	44				=	=
23	101	88	72	63	52	40					
24	93	81	67	57	48	37					
25	86	75	61	53	44	34					
26	79	69	57	49	41	32					
27	73	64	53	45	38	29					
28	68	60	49	42	35	27					
29	64	56	46	39	33	25					
30	59	52	43	37	31	24					
31	56	49	40	34	29	22					
32	52	46	37	32	27	21					
33	=	=	35	30	25	20					
34			=	29	24	18					
35				=	=	17					
36						=					
37											
38											
39											
40											
Properties											
Area, In.^{2}	14.0	11.6	8.97	7.59	6.17	4.67	9.74	7.58	6.43	5.24	3.98
I_x, In.^{4}	133	115	92.5	79.8	66.1	51.1	80.8	66.3	57.7	48.2	37.6
I_y, In.^{4}	51.9	45.2	36.8	32.0	26.6	20.7	13.2	11.2	9.88	8.38	6.63
Ratio r_x / r_y	1.60	1.60	1.59	1.58	1.58	1.57	2.47	2.43	2.42	2.40	2.38
r_y, In.	1.92	1.97	2.03	2.05	2.08	2.10	1.16	1.21	1.24	1.27	1.29
B_x, Bending Factor	0.474	0.454	0.436	0.428	0.420	0.411	0.542	0.514	0.501	0.489	0.476
B_y, Bending Factor	0.674	0.642	0.609	0.593	0.580	0.564	1.11	1.02	0.976	0.938	0.900
$a_x \div 10^6$	19.9	17.2	13.8	11.9	9.87	7.63	12.1	9.90	8.62	7.20	5.61
$a_y \div 10^6$	7.75	6.75	5.50	4.78	3.97	3.09	1.97	1.67	1.48	1.25	0.990

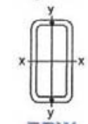
*Slender element section. Width-Thickness and/or Depth-Thickness ratio exceeds AISC "Specification" Section B5.1 limiting value of $253 / \sqrt{Fy}$.
Note: Double Horizontal Line indicates $k\ell/r$ limit of 200.

54

HSS / Rectangular Structural Steel Tubing

Allowable Concentric Loads in Kips

Fy=50



ERW

Nominal Size		18 x 6					16 x 12			16 x 8			
Wall Thickness		5/8	1/2	3/8	5/16	1/4	1/2	3/8	5/16	5/8	1/2	3/8	5/16
Weight Per Foot		93.34	76.07	58.10	48.86	39.43	89.68	68.31	57.36	93.34	76.07	58.10	48.86
Design Wall Thickness		0.581	0.465	0.349*	0.291*	0.233*	0.465	0.349*	0.291*	0.581	0.465	0.349*	0.291*
		F_y = 50 ksi											
Effective length KL in feet	0	771	627	421	324	236	738	528	415	771	627	448	348
	2	753	612	414	319	232	730	523	412	758	616	442	344
	3	741	604	410	316	230	725	521	410	750	610	439	341
	4	729	594	405	313	228	720	518	408	741	603	435	338
	5	716	583	400	309	226	715	515	405	732	596	431	335
	6	701	571	394	305	223	709	512	403	722	588	426	332
	7	685	559	388	301	220	703	508	400	711	579	422	329
	8	669	546	382	296	217	697	505	398	700	570	417	325
	9	651	532	375	291	214	690	501	395	688	561	411	321
	10	632	517	367	286	210	683	497	392	676	551	406	317
	11	613	502	359	280	207	676	493	389	663	541	400	313
	12	592	486	351	274	203	669	488	386	649	530	394	308
	13	571	469	342	268	199	661	484	382	635	519	387	304
	14	549	451	333	262	194	654	479	379	620	507	380	299
	15	526	433	322	255	190	646	475	375	605	495	373	294
	16	502	414	312	247	185	637	470	372	589	482	365	288
	17	477	395	300	239	180	629	464	368	573	470	358	283
	18	451	374	288	231	174	620	459	364	557	456	349	277
	19	425	353	275	222	169	611	454	360	539	443	341	271
	20	397	332	260	212	162	601	448	356	522	429	331	264
	21	368	309	244	202	156	592	442	352	504	414	321	258
	22	339	286	227	191	149	582	436	347	485	399	309	251
	23	310	262	209	178	141	572	430	343	466	384	298	243
	24	285	241	192	164	133	562	424	338	446	368	286	236
	25	262	222	177	151	124	552	417	333	426	352	274	227
	26	242	205	163	140	115	541	410	328	405	336	262	219
	27	225	190	152	130	106	530	403	323	383	319	249	210
	28	209	177	141	121	99	519	396	318	361	302	236	200
	29	195	165	131	113	92	508	388	312	339	284	223	190
	30	182	154	123	105	86	496	380	307	317	265	209	178
	31	171	144	115	99	81	484	371	301	297	249	196	167
	32	160	135	108	92	76	473	362	295	278	233	184	157
	33	151	127	101	87	71	460	353	289	262	219	173	148
	34	142	120	96	82	67	448	344	283	247	207	163	139
	35	134	113	90	77	63	435	334	276	233	195	154	131
	36	126	107	85	73	60	423	325	269	220	184	145	124
	37	120	101	81	69	57	409	315	262	208	175	138	117
	38	114	96	76	66	54	396	305	255	197	165	130	111
	39	108	91	73	62	51	383	295	248	187	157	124	106
	40	102	87	69	59	48	369	285	240	178	149	118	100
PROPERTIES													
Area, In.^{2}		25.7	20.9	16.0	13.4	10.8	24.6	18.7	15.7	25.7	20.9	16.0	13.4
I_x, In.^{4}		923	770	602	513	419	904	702	595	815	679	531	451
I_y, In.^{4}		158	134	106	91.3	75.1	581	452	384	274	230	181	155
Ratio r_x / r_y		2.42	2.40	2.38	2.37	2.36	1.25	1.25	1.24	1.72	1.72	1.71	1.71
r_y, In.		2.48	2.53	2.58	2.61	2.63	4.86	4.91	4.94	3.27	3.32	3.37	3.40
B_x, Bending Factor		0.251	0.244	0.239	0.235	0.232	0.218	0.213	0.211	0.252	0.246	0.241	0.238
B_y, Bending Factor		0.488	0.468	0.453	0.440	0.431	0.254	0.248	0.245	0.375	0.363	0.354	0.346
a_x, ÷ 10^6		138	115	89.9	76.6	62.6	135	105	88.9	122	101	79.3	67.3
a_y, ÷ 10^6		23.6	20.0	15.8	13.6	11.2	86.8	67.5	57.3	40.9	34.3	27.0	23.1

*Slender element section. Width-Thickness and/or Depth-Thickness ratio exceeds AISC "Specification" Section B5.1 limiting value of 253 / $\sqrt{Fy}$.

45

Appendix E

RS Means 2009 Data

32 91 Planting Preparation

32 91 19 – Landscape Grading

32 91 19.13 Topsoil Placement and Grading		Crew	Daily Output	Labor-Hours	Unit	Material	2009 Bare Costs Labor	Equipment	Total	Total Incl O&P
0300	Fine grade, base course for paving, see Div. 32 11 23.23									
0400	Spread from pile to rough finish grade, F.E. loader, 1.5 CY	B-10S	200	.060	C.Y.		2.29	1.64	3.93	5.30
0500	Up to 200' radius, by hand	1 Clab	14	.571			18.05		18.05	28
0600	Top dress by hand, 1 C.Y. for 600 S.F.	"	11.50	.696	↓	20.50	22		42.50	57
0700	Furnish and place, truck dumped, screened, 4" deep	B-10S	1300	.009	S.Y.	2.59	.35	.25	3.19	3.66
0800	6" deep	"	820	.015	"	3.32	.56	.40	4.28	4.94

32 92 Turf and Grasses

32 92 19 – Seeding

32 92 19.14 Seeding, Athletic Fields		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**SEEDING, ATHLETIC FIELDS**									
0020	Seeding, athletic fields, athletic field mix, 8#/M.S.F. push spreader	1 Clab	8	1	M.S.F.	15.35	31.50		46.85	66
0100	Tractor spreader	B-66	52	.154		15.35	6	4.45	25.80	31
0200	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		16.90	10.50	7.25	34.65	42.50
0400	Birdsfoot trefoil, .45#/M.S.F., push spreader	1 Clab	8	1		7.80	31.50		39.30	57.50
0500	Tractor spreader	B-66	52	.154		7.80	6	4.45	18.25	22.50
0600	Hydro or air seeding,with mulch & fertil.	B-81	80	.300		15	10.50	7.25	32.75	40.50
0800	Bluegrass, 4#/M.S.F., common, push spreader	1 Clab	8	1		16.35	31.50		47.85	67
0900	Tractor spreader	B-66	52	.154		16.35	6	4.45	26.80	32
1000	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		27	10.50	7.25	44.75	53.50
1100	Baron, push spreader	1 Clab	8	1		22	31.50		53.50	73
1200	Tractor spreader	B-66	52	.154		22	6	4.45	32.45	38
1300	Hydro or air seeding, with mulch & fertil.	B-81	80	.300		30	10.50	7.25	47.75	57
1500	Clover, 0.67#/M.S.F., white, push spreader	1 Clab	8	1		1.43	31.50		32.93	50.50
1600	Tractor spreader	B-66	52	.154		1.43	6	4.45	11.88	15.50
1700	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		7.85	10.50	7.25	25.60	32.50
1800	Ladino, push spreader	1 Clab	8	1		5.60	31.50		37.10	55
1900	Tractor spreader	B-66	52	.154		5.60	6	4.45	16.05	20
2000	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		24.50	10.50	7.25	42.25	51
2200	Fescue 5.5#/M.S.F., tall, push spreader	1 Clab	8	1		11.10	31.50		42.60	61
2300	Tractor spreader	B-66	52	.154		11.10	6	4.45	21.55	26
2400	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		36.50	10.50	7.25	54.25	64.50
2500	Chewing, push spreader	1 Clab	8	1		11.10	31.50		42.60	61
2600	Tractor spreader	B-66	52	.154		11.10	6	4.45	21.55	26
2700	Hydro or air seeding, with mulch and fertil.	B-81	80	.300		36.50	10.50	7.25	54.25	64.50
2900	Crown vetch, 4#/M.S.F., push spreader	1 Clab	8	1		41	31.50		72.50	94
3000	Tractor spreader	B-66	52	.154		41	6	4.45	51.45	59
3100	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		56	10.50	7.25	73.75	85.50
3300	Rye, 10#/M.S.F., annual, push spreader	1 Clab	8	1		23	31.50		54.50	74
3400	Tractor spreader	B-66	52	.154		23	6	4.45	33.45	39
3500	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		50	10.50	7.25	67.75	79
3600	Fine textured, push spreader	1 Clab	8	1		23	31.50		54.50	74
3700	Tractor spreader	B-66	52	.154		23	6	4.45	33.45	39
3800	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		50	10.50	7.25	67.75	79
4000	Shade mix, 6#/M.S.F., push spreader	1 Clab	8	1		10.70	31.50		42.20	61
4100	Tractor spreader	B-66	52	.154		10.70	6	4.45	21.15	25.50
4200	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		23.50	10.50	7.25	41.25	50
4400	Slope mix, 6#/M.S.F., push spreader	1 Clab	8	1		10.70	31.50		42.20	61
4500	Tractor spreader	B-66	52	.154		10.70	6	4.45	21.15	25.50
4600	Hydro or air seeding, with mulch and fertilizer	B-81	80	.300		27	10.50	7.25	44.75	53.50
4800	Turf mix, 4#/M.S.F., push spreader	1 Clab	8	1		7.15	31.50		38.65	57

32 93 Plants

32 93 43 – Trees

32 93 43.10 Planting		Crew	Daily Output	Labor-Hours	Unit	Material	2009 Bare Costs Labor	Equipment	Total	Total Incl O&P
0010	**PLANTING**									
0011	Trees, shrubs and ground cover									
0100	Light soil									
0110	Bare root seedlings, 3″ to 5″ height	1 Clab	960	.008	Ea.		.26		.26	.41
0120	6″ to 10″		520	.015			.49		.49	.75
0130	11″ to 16″		370	.022			.68		.68	1.06
0140	17″ to 24″		210	.038			1.20		1.20	1.87
0200	Potted, 2-1/4″ diameter		840	.010			.30		.30	.47
0210	3″ diameter		700	.011			.36		.36	.56
0220	4″ diameter		620	.013			.41		.41	.63
0300	Container, 1 gallon	2 Clab	84	.190			6		6	9.35
0310	2 gallon		52	.308			9.70		9.70	15.10
0320	3 gallon		40	.400			12.65		12.65	19.60
0330	5 gallon		29	.552			17.45		17.45	27
0400	Bagged and burlapped, 12″ diameter ball, by hand		19	.842			26.50		26.50	41.50
0410	Backhoe/loader, 48 H.P.	B-6	40	.600			20.50	7.35	27.85	39.50
0415	15″ diameter, by hand	2 Clab	16	1			31.50		31.50	49
0416	Backhoe/loader, 48 H.P.	B-6	30	.800			27.50	9.80	37.30	53
0420	18″ diameter by hand	2 Clab	12	1.333			42		42	65.50
0430	Backhoe/loader, 48 H.P.	B-6	27	.889			30.50	10.90	41.40	58.50
0440	24″ diameter by hand	2 Clab	9	1.778			56		56	87
0450	Backhoe/loader 48 H.P.	B-6	21	1.143			39	14	53	75
0470	36″ diameter, backhoe/loader, 48 H.P.	″	17	1.412			48	17.30	65.30	92.50
0550	Medium soil									
0560	Bare root seedlings, 3″ to 5″	1 Clab	672	.012	Ea.		.38		.38	.58
0561	6″ to 10″		364	.022			.69		.69	1.08
0562	11″ to 16″		260	.031			.97		.97	1.51
0563	17″ to 24″		145	.055			1.74		1.74	2.70
0570	Potted, 2-1/4″ diameter		590	.014			.43		.43	.66
0572	3″ diameter		490	.016			.52		.52	.80
0574	4″ diameter		435	.018			.58		.58	.90
0590	Container, 1 gallon	2 Clab	59	.271			8.55		8.55	13.30
0592	2 gallon		36	.444			14.05		14.05	22
0594	3 gallon		28	.571			18.05		18.05	28
0595	5 gallon		20	.800			25.50		25.50	39
0600	Bagged and burlapped, 12″ diameter ball, by hand		13	1.231			39		39	60.50
0605	Backhoe/loader, 48 H.P.	B-6	28	.857			29	10.50	39.50	56.50
0607	15″ diameter, by hand	2 Clab	11.20	1.429			45		45	70
0608	Backhoe/loader, 48 H.P.	B-6	21	1.143			39	14	53	75
0610	18″ diameter, by hand	2 Clab	8.50	1.882			59.50		59.50	92
0615	Backhoe/loader, 48 H.P.	B-6	19	1.263			43	15.45	58.45	83
0620	24″ diameter, by hand	2 Clab	6.30	2.540			80.50		80.50	124
0625	Backhoe/loader, 48 H.P.	B-6	14.70	1.633			55.50	20	75.50	108
0630	36″ diameter, backhoe/loader, 48 H.P.	″	12	2			68	24.50	92.50	131
0700	Heavy or stoney soil									
0710	Bare root seedlings, 3″ to 5″	1 Clab	470	.017	Ea.		.54		.54	.83
0711	6″ to 10″		255	.031			.99		.99	1.54
0712	11″ to 16″		182	.044			1.39		1.39	2.15
0713	17″ to 24″		101	.079			2.50		2.50	3.88
0720	Potted, 2-1/4″ diameter		360	.022			.70		.70	1.09
0722	3″ diameter		343	.023			.74		.74	1.14
0724	4″ diameter		305	.026			.83		.83	1.29
0730	Container, 1 gallon	2 Clab	41.30	.387			12.25		12.25	19

300

33 21 Water Supply Wells

33 21 13 – Public Water Supply Wells

33 21 13.10 Wells and Accessories		Crew	Daily Output	Labor-Hours	Unit	2009 Bare Costs Material	Labor	Equipment	Total	Total Incl O&P
0010	**WELLS & ACCESSORIES**									
0011	Domestic									
0100	Drilled, 4" to 6" diameter	B-23	120	.333	L.F.		10.65	23	33.65	42
0200	8" diameter	"	95.20	.420	"		13.45	29	42.45	53
0400	Gravel pack well, 40' deep, incl. gravel & casing, complete									
0500	24" diameter casing x 18" diameter screen	B-23	.13	307	Total	30,600	9,850	21,400	61,850	72,500
0600	36" diameter casing x 18" diameter screen		.12	333	"	32,900	10,700	23,100	66,700	78,000
0800	Observation wells, 1-1/4" riser pipe		163	.245	V.L.F.	16.85	7.85	17.05	41.75	49.50
0900	For flush Buffalo roadway box, add	1 Skwk	16.60	.482	Ea.	46	19.70		65.70	81
1200	Test well, 2-1/2" diameter, up to 50' deep (15 to 50 GPM)	B-23	1.51	26.490	"	690	850	1,850	3,390	4,100
1300	Over 50' deep, add	"	121.80	.328	L.F.	18.35	10.50	23	51.85	61.50
1500	Pumps, installed in wells to 100' deep, 4" submersible									
1510	1/2 H.P.	Q-1	3.22	4.969	Ea.	460	218		678	830
1520	3/4 H.P.		2.66	6.015		565	264		829	1,025
1600	1 H.P.		2.29	6.987		615	305		920	1,150
1700	1-1/2 H.P.	Q-22	1.60	10		800	440	480	1,720	2,075
1800	2 H.P.		1.33	12.030		1,200	530	580	2,310	2,725
1900	3 H.P.		1.14	14.035		1,975	615	675	3,265	3,850
2000	5 H.P.		1.14	14.035		2,775	615	675	4,065	4,725
3000	Pump, 6" submersible, 25' to 150' deep, 25 H.P., 249 to 297 GPM		.89	17.978		5,425	790	865	7,080	8,100
3100	25' to 500' deep, 30 H.P., 100 to 300 GPM		.73	21.918		6,300	960	1,050	8,310	9,525
8000	Steel well casing	B-23A	3020	.008	Lb.	.87	.28	.88	2.03	2.36
9950	See Div. 31 23 19.40 for wellpoints									
9960	See Div. 31 23 19.30 for drainage wells									

33 21 13.20 Water Supply Wells, Pumps		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**WATER SUPPLY WELLS, PUMPS**									
0011	With pressure control									
1000	Deep well, jet, 42 gal. galvanized tank									
1040	3/4 HP	1 Plum	.80	10	Ea.	685	490		1,175	1,475
3000	Shallow well, jet, 30 gal. galvanized tank									
3040	1/2 HP	1 Plum	2	4	Ea.	495	195		690	840

33 31 Sanitary Utility Sewerage Piping

33 31 13 – Public Sanitary Utility Sewerage Piping

33 31 13.15 Sewage Collection, Concrete Pipe		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**SEWAGE COLLECTION, CONCRETE PIPE**									
0020	See Div. 33 41 13.60 for sewage/drainage collection, concrete pipe									

33 31 13.25 Sewage Collection, Polyvinyl Chloride Pipe		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**SEWAGE COLLECTION, POLYVINYL CHLORIDE PIPE**									
0020	Not including excavation or backfill									
2000	20' lengths, S.D.R. 35, B&S, 4" diameter	B-20	375	.064	L.F.	1.66	2.26		3.92	5.35
2040	6" diameter		350	.069		3.40	2.42		5.82	7.50
2080	13' lengths , S.D.R. 35, B&S, 8" diameter		335	.072		7.05	2.53		9.58	11.65
2120	10" diameter	B-21	330	.085		11.15	3.09	.39	14.63	17.45
2160	12" diameter		320	.088		12.70	3.18	.40	16.28	19.30
2200	15" diameter		240	.117		12.10	4.24	.54	16.88	20.50
4000	Piping, DWV PVC, no exc/bkfill, 10' L, Sch 40, 4" diameter	B-20	375	.064		3.84	2.26		6.10	7.75
4010	6" diameter		350	.069		7.65	2.42		10.07	12.15
4020	8" diameter		335	.072		13.30	2.53		15.83	18.55

623

31 63 Bored Piles

31 63 29 – Drilled Concrete Piers and Shafts

	31 63 29.13 Uncased Drilled Concrete Piers	Crew	Daily Output	Labor-Hours	Unit	2010 Bare Costs Material	Labor	Equipment	Total	Total Incl O&P
0070	12″ diameter	B-43	420	.114	V.L.F.	8.75	4.14	6.15	19.04	23
0075	14″ diameter		360	.133		11.80	4.82	7.20	23.82	28.50
0080	16″ diameter		300	.160		15.90	5.80	8.65	30.35	36
0085	18″ diameter		240	.200		19.70	7.25	10.80	37.75	44.50
0100	Cast in place, thin wall shell pile, straight sided,									
0110	not incl. reinforcing, 8″ diam., 16 ga., 5.8 lb./L.F.	B-19	700	.091	V.L.F.	9.10	3.78	2.76	15.64	18.95
0200	10″ diameter, 16 ga. corrugated, 7.3 lb./L.F.		650	.098		11.90	4.07	2.97	18.94	22.50
0300	12″ diameter, 16 ga. corrugated, 8.7 lb./L.F.		600	.107		15.45	4.41	3.22	23.08	27.50
0400	14″ diameter, 16 ga. corrugated, 10.0 lb./L.F.		550	.116		18.15	4.81	3.51	26.47	31.50
0500	16″ diameter, 16 ga. corrugated, 11.6 lb./L.F.		500	.128		22.50	5.30	3.87	31.67	37
0800	Cast in place friction pile, 50′ long, fluted,									
0810	tapered steel, 4000 psi concrete, no reinforcing									
0900	12″ diameter, 7 ga.	B-19	600	.107	V.L.F.	27.50	4.41	3.22	35.13	40.50
1000	14″ diameter, 7 ga.		560	.114		29.50	4.72	3.45	37.67	43.50
1100	16″ diameter, 7 ga.		520	.123		35	5.10	3.72	43.82	50.50
1200	18″ diameter, 7 ga.		480	.133		41	5.50	4.03	50.53	58
1300	End bearing, fluted, constant diameter,									
1320	4000 psi concrete, no reinforcing									
1340	12″ diameter, 7 ga.	B-19	600	.107	V.L.F.	28.50	4.41	3.22	36.13	42
1360	14″ diameter, 7 ga.		560	.114		35.50	4.72	3.45	43.67	50
1380	16″ diameter, 7 ga.		520	.123		41.50	5.10	3.72	50.32	57.50
1400	18″ diameter, 7 ga.		480	.133		45.50	5.50	4.03	55.03	63

	31 63 29.20 Cast In Place Piles, Adds	Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**CAST IN PLACE PILES, ADDS**									
1500	For reinforcing steel, add				Lb.	.80			.80	.88
1700	For ball or pedestal end, add	B-19	11	5.818	C.Y.	146	240	176	562	730
1900	For lengths above 60′, concrete, add	″	11	5.818	″	152	240	176	568	735
2000	For steel thin shell, pipe only				Lb.	1.08			1.08	1.19

340

31 63 Bored Piles

31 63 26 – Drilled Caissons

31 63 26.13 Fixed End Cassion Piles

	31 63 26.13 Fixed End Cassion Piles	Crew	Daily Output	Labor-Hours	Unit	Material	2010 Bare Costs Labor	Equipment	Total	Total Incl O&P
2900	60" diameter, 0.727 C.Y./L.F.	B-49	7	12.571	V.L.F.	85	480	530	1,095	1,425
3000	72" diameter, 1.05 C.Y./L.F.		6	14.667		123	560	615	1,298	1,675
3100	84" diameter, 1.43 C.Y./L.F.		5	17.600		167	675	740	1,582	2,025
3200	For bell excavation and concrete, add									
3220	4' bell diameter, 24" shaft, 0.444 C.Y.	B-49	10.90	8.073	Ea.	43	310	340	693	900
3240	6' bell diameter, 30" shaft, 1.57 C.Y.		3.10	28.387		152	1,100	1,200	2,452	3,150
3260	8' bell diameter, 36" shaft, 3.72 C.Y.		1.30	67.692		360	2,600	2,850	5,810	7,500
3280	9' bell diameter, 48" shaft, 4.48 C.Y.		1.10	80		435	3,075	3,350	6,860	8,875
3300	10' bell diameter, 60" shaft, 5.24 C.Y.		.90	97.778		510	3,750	4,100	8,360	10,800
3320	12' bell diameter, 72" shaft, 8.74 C.Y.		.60	146		850	5,625	6,150	12,625	16,300
3340	14' bell diameter, 84" shaft, 13.6 C.Y.		.40	220		1,325	8,425	9,250	19,000	24,600
3600	For rock excavation, sockets, add, minimum		120	.733	C.F.		28	31	59	77
3650	Average		95	.926			35.50	39	74.50	97.50
3700	Maximum		48	1.833			70.50	77	147.50	193
3900	For 50' to 100' deep, add				V.L.F.				7%	7%
4000	For 100' to 150' deep, add								25%	25%
4100	For 150' to 200' deep, add								30%	30%
4200	For casings left in place, add				Lb.	.97			.97	1.07
4300	For other than 50 lb. reinf. per C.Y., add or deduct				"	1.03			1.03	1.13
4400	For steel "I" beam cores, add	B-49	8.30	10.602	Ton	1,750	405	445	2,600	3,050
4500	Load and haul excess excavation, 2 miles	B-34B	178	.045	L.C.Y.		1.49	3.75	5.24	6.40
4600	For mobilization, 50 mile radius, rig to 36"	B-43	2	24	Ea.		870	1,300	2,170	2,750
4650	Rig to 84"	B-48	1.75	32			1,175	1,675	2,850	3,650
4700	For low headroom, add								50%	
4750	For difficult access, add								25%	
5000	Bottom inspection	1 Skwk	1.20	6.667			284		284	435

31 63 26.16 Concrete Caissons for Marine Construction

	31 63 26.16 Concrete Caissons for Marine Construction	Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**CONCRETE CAISSONS FOR MARINE CONSTRUCTION**									
0100	Caissons, incl. mobilization and demobilization, up to 50 miles									
0200	Uncased shafts, 30 to 80 tons cap., 17" diam., 10' depth	B-44	88	.727	V.L.F.	19.40	29.50	21	69.90	91
0300	25' depth		165	.388		13.85	15.80	11.15	40.80	52.50
0400	80 to 150 ton capacity, 22" diameter, 10' depth		80	.800		24.50	32.50	23	80	103
0500	20' depth		130	.492		19.40	20	14.15	53.55	68.50
0700	Cased shafts, 10 to 30 ton capacity, 10-5/8" diam., 20' depth		175	.366		13.85	14.90	10.50	39.25	50.50
0800	30' depth		240	.267		12.95	10.85	7.65	31.45	40
0850	30 to 60 ton capacity, 12" diameter, 20' depth		160	.400		19.40	16.25	11.50	47.15	59.50
0900	40' depth		230	.278		14.90	11.30	8	34.20	43
1000	80 to 100 ton capacity, 16" diameter, 20' depth		160	.400		27.50	16.25	11.50	55.25	68.50
1100	40' depth		230	.278		26	11.30	8	45.30	55
1200	110 to 140 ton capacity, 17-5/8" diameter, 20' depth		160	.400		30	16.25	11.50	57.75	71
1300	40' depth		230	.278		27.50	11.30	8	46.80	57
1400	140 to 175 ton capacity, 19" diameter, 20' depth		130	.492		32.50	20	14.15	66.65	82.50
1500	40' depth		210	.305		30	12.40	8.75	51.15	62
1700	Over 30' long, L.F. cost tends to be lower									
1900	Maximum depth is about 90'									

31 63 29 – Drilled Concrete Piers and Shafts

31 63 29.13 Uncased Drilled Concrete Piers

	31 63 29.13 Uncased Drilled Concrete Piers	Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**UNCASED DRILLED CONCRETE PIERS**									
0020	Unless specified otherwise, not incl. pile caps or mobilization									
0050	Cast in place augered piles, no casing or reinforcing									
0060	8" diameter	B-43	540	.089	V.L.F.	3.91	3.22	4.80	11.93	14.50
0065	10" diameter		480	.100		6.20	3.62	5.40	15.22	18.30

339

31 62 Driven Piles

31 62 33 – Drilled Micropiles

31 62 33.10 Drilled Micropiles Metal Pipe		Crew	Daily Output	Labor-Hours	Unit	Material	2010 Bare Costs Labor	Equipment	Total	Total Incl O&P
5080	More than 40′	B-48	135	.415	V.L.F.	25	15.30	22	62.30	75.50
5120	Friction, loose sand and gravel		107	.523		43	19.30	27.50	89.80	108
5160	Dense sand and gravel		135	.415		25	15.30	22	62.30	75.50
5200	Uncased, up to 10 ton capacity, 20′		135	.415		25.50	15.30	22	62.80	75.50

31 63 Bored Piles

31 63 26 – Drilled Caissons

31 63 26.13 Fixed End Cassion Piles

		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**FIXED END CASSION PILES** R316326-60									
0015	Including excavation, concrete, 50 lbs reinforcing									
0020	per C.Y., not incl. mobilization, boulder removal, disposal									
0100	Open style, machine drilled, to 50′ deep, in stable ground, no									
0110	casings or ground water, 18″ diam., 0.065 C.Y./L.F.	B-43	200	.240	V.L.F.	7.60	8.70	12.95	29.25	36
0200	24″ diameter, 0.116 C.Y./L.F.		190	.253		13.55	9.15	13.65	36.35	44
0300	30″ diameter, 0.182 C.Y./L.F.		150	.320		21.50	11.60	17.25	50.35	60
0400	36″ diameter, 0.262 C.Y./L.F.		125	.384		30.50	13.90	20.50	64.90	77.50
0500	48″ diameter, 0.465 C.Y./L.F.		100	.480		54.50	17.35	26	97.85	115
0600	60″ diameter, 0.727 C.Y./L.F.		90	.533		85	19.30	29	133.30	155
0700	72″ diameter, 1.05 C.Y./L.F.		80	.600		123	21.50	32.50	177	204
0800	84″ diameter, 1.43 C.Y./L.F.		75	.640		167	23	34.50	224.50	258
1000	For bell excavation and concrete, add									
1020	4′ bell diameter, 24″ shaft, 0.444 C.Y.	B-43	20	2.400	Ea.	43	87	130	260	325
1040	6′ bell diameter, 30″ shaft, 1.57 C.Y.		5.70	8.421		152	305	455	912	1,125
1060	8′ bell diameter, 36″ shaft, 3.72 C.Y.		2.40	20		360	725	1,075	2,160	2,700
1080	9′ bell diameter, 48″ shaft, 4.48 C.Y.		2	24		435	870	1,300	2,605	3,225
1100	10′ bell diameter, 60″ shaft, 5.24 C.Y.		1.70	28.235		510	1,025	1,525	3,060	3,775
1120	12′ bell diameter, 72″ shaft, 8.74 C.Y.		1	48		850	1,725	2,600	5,175	6,425
1140	14′ bell diameter, 84″ shaft, 13.6 C.Y.		.70	68.571		1,325	2,475	3,700	7,500	9,300
1200	Open style, machine drilled, to 50′ deep, in wet ground, pulled									
1300	casing and pumping, 18″ diameter, 0.065 C.Y./L.F.	B-48	160	.350	V.L.F.	7.60	12.90	18.45	38.95	48.50
1400	24″ diameter, 0.116 C.Y./L.F.		125	.448		13.55	16.55	23.50	53.60	66
1500	30″ diameter, 0.182 C.Y./L.F.		85	.659		21.50	24.50	34.50	80.50	98.50
1600	36″ diameter, 0.262 C.Y./L.F.		60	.933		30.50	34.50	49	114	140
1700	48″ diameter, 0.465 C.Y./L.F.	B-49	55	1.600		54.50	61.50	67	183	228
1800	60″ diameter, 0.727 C.Y./L.F.		35	2.514		85	96.50	106	287.50	360
1900	72″ diameter, 1.05 C.Y./L.F.		30	2.933		123	112	123	358	445
2000	84″ diameter, 1.43 C.Y./L.F.		25	3.520		167	135	148	450	555
2100	For bell excavation and concrete, add									
2120	4′ bell diameter, 24″ shaft, 0.444 C.Y.	B-48	19.80	2.828	Ea.	43	104	149	296	370
2140	6′ bell diameter, 30″ shaft, 1.57 C.Y.		5.70	9.825		152	365	515	1,032	1,300
2160	8′ bell diameter, 36″ shaft, 3.72 C.Y.		2.40	23.333		360	860	1,225	2,445	3,050
2180	9′ bell diameter, 48″ shaft, 4.48 C.Y.	B-49	3.30	26.667		435	1,025	1,125	2,585	3,275
2200	10′ bell diameter, 60″ shaft, 5.24 C.Y.		2.80	31.429		510	1,200	1,325	3,035	3,850
2220	12′ bell diameter, 72″ shaft, 8.74 C.Y.		1.60	55		850	2,100	2,300	5,250	6,700
2240	14′ bell diameter, 84″ shaft, 13.6 C.Y.		1	88		1,325	3,375	3,700	8,400	10,700
2300	Open style, machine drilled, to 50′ deep, in soft rocks and									
2400	medium hard shales, 18″ diameter, 0.065 C.Y./L.F.	B-49	50	1.760	V.L.F.	7.60	67.50	74	149.10	193
2500	24″ diameter, 0.116 C.Y./L.F.		30	2.933		13.55	112	123	248.55	325
2600	30″ diameter, 0.182 C.Y./L.F.		20	4.400		21.50	169	185	375.50	485
2700	36″ diameter, 0.262 C.Y./L.F.		15	5.867		30.50	225	246	501.50	650
2800	48″ diameter, 0.465 C.Y./L.F.		10	8.800		54.50	335	370	759.50	980

338

04 22 Concrete Unit Masonry

04 22 10 – Concrete Masonry Units

04 22 10.44 Glazed Concrete Block		Crew	Daily Output	Labor-Hours	Unit	Material	Labor (2009 Bare Costs)	Equipment (2009 Bare Costs)	Total (2009 Bare Costs)	Total Incl O&P
1500	Cove base, 8" x 16", 2" thick	D-8	315	.127	L.F.	11	4.72		15.72	19.25
1550	4" thick		285	.140		7.15	5.20		12.35	15.75
1600	6" thick		265	.151		7.70	5.60		13.30	16.95
1650	8" thick		245	.163		8.10	6.05		14.15	18.10

04 24 Adobe Unit Masonry

04 24 16 – Manufactured Adobe Unit Masonry

04 24 16.06 Adobe Brick			Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**ADOBE BRICK**, Semi-stabilized, with cement mortar										
0060	Brick, 10" x 4" x 14", 2.6/S.F.	G	D-8	560	.071	S.F.	3.54	2.65		6.19	7.95
0080	12" x 4" x 16", 2.3/S.F.	G		580	.069		4.50	2.56		7.06	8.85
0100	10" x 4" x 16", 2.3/S.F.	G		590	.068		4.27	2.52		6.79	8.50
0120	8" x 4" x 16", 2.3/S.F.	G		560	.071		3.34	2.65		5.99	7.70
0140	4" x 4" x 16", 2.3/S.F.	G		540	.074		2.55	2.75		5.30	7
0160	6" x 4" x 16", 2.3/S.F.	G		540	.074		2.58	2.75		5.33	7
0180	4" x 4" x 12", 3.0/S.F.	G		520	.077		2.29	2.86		5.15	6.85
0200	8" x 4" x 12", 3.0/S.F.	G		520	.077		2.52	2.86		5.38	7.10

04 25 Unit Masonry Panels

04 25 20 – Pre-Fabricated Masonry Panels

04 25 20.10 Brick and Epoxy Mortar Panels		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**BRICK AND EPOXY MORTAR PANELS**									
0020	Prefabricated brick & epoxy mortar, 4" thick, minimum	C-11	775	.093	S.F.	9.25	4.07	2.44	15.76	19.90
0100	Maximum	"	500	.144		10.75	6.30	3.78	20.83	27
0200	For 2" concrete back-up, add					50%				
0300	For 1" urethane & 3" concrete back-up, add					70%				

04 27 Multiple-Wythe Unit Masonry

04 27 10 – Multiple-Wythe Masonry

04 27 10.30 Brick Walls		Crew	Daily Output	Labor-Hours	Unit	Material	Labor	Equipment	Total	Total Incl O&P
0010	**BRICK WALLS**, including mortar, excludes scaffolding									
0020	Estimating by number of brick									
0140	Face brick, 4" thick wall, 6.75 brick/S.F.	D-8	1.45	27.586	M	830	1,025		1,855	2,475
0150	Common brick, 4" thick wall, 6.75 brick/S.F.		1.60	25		430	930		1,360	1,875
0204	8" thick, 13.50 bricks per S.F.		1.80	22.222		445	825		1,270	1,750
0250	12" thick, 20.25 bricks per S.F.		1.90	21.053		450	780		1,230	1,675
0304	16" thick, 27.00 bricks per S.F.		2	20		455	745		1,200	1,625
0500	Reinforced, face brick, 4" thick wall, 6.75 brick/S.F.		1.40	28.571		870	1,050		1,920	2,550
0520	Common brick, 4" thick wall, 6.75 brick/S.F.		1.55	25.806		470	960		1,430	1,975
0550	8" thick, 13.50 bricks per S.F.		1.75	22.857		485	850		1,335	1,825
0600	12" thick, 20.25 bricks per S.F.		1.85	21.622		490	805		1,295	1,775
0650	16" thick, 27.00 bricks per S.F.		1.95	20.513		495	760		1,255	1,700
0790	Alternate method of figuring by square foot									
0800	Face brick, 4" thick wall, 6.75 brick/S.F.	D-8	215	.186	S.F.	5.60	6.90		12.50	16.65
0850	Common brick, 4" thick wall, 6.75 brick/S.F.		240	.167		2.90	6.20		9.10	12.60
0900	8" thick, 13.50 bricks per S.F.		135	.296		6.05	11		17.05	23.50
1000	12" thick, 20.25 bricks per S.F.		95	.421		9.10	15.65		24.75	33.50

39

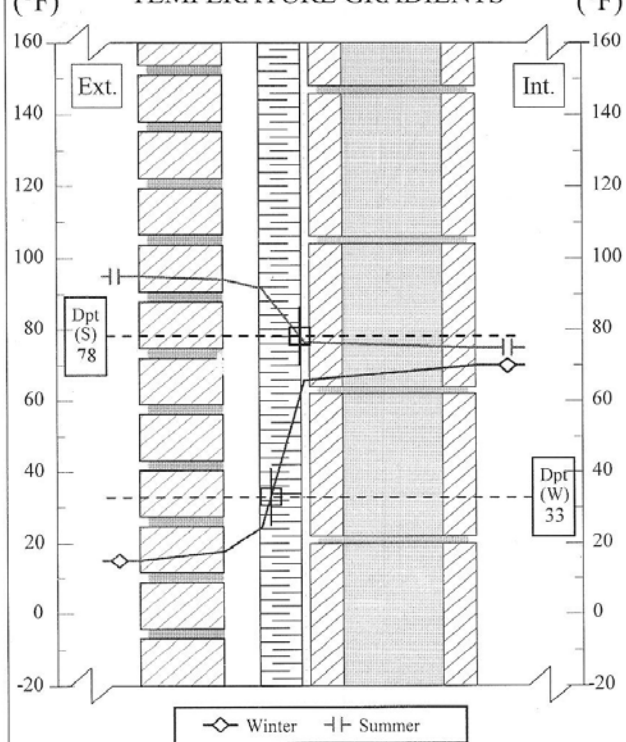
Appendix F

R Value Analysis

R VALUE ANALYSIS

The Heat, Air and Moisture Building Science Toolbox - V.1B-E/U (11)

WALL SECTION AND TEMPERATURE GRADIENTS



PROJECT

Name	Pershing Hill Elementary
Number	1
City	Washington, DC
Date	3/4/2010
Analysis by:	Mitchell Reiner
Wall Type	
Option	

CLIMATIC CONDITIONS

	Winter		Summer	
	Int.	Ext.	Int.	Ext.
Temp (°F)	70	15	75	95
RH (%)	25	70	50	57
DPT (°F)	33	9	56	78

PENNSYLVANIA STATE UNIVERSITY

104 ENGINEERING, UNIT A
UNIVERSITY PARK, PA, USA, 16802

	Generic Material	Manufacturer	Model No.	Thick (in.)	RVal (R)	W.Temp. (°F)	S.Temp. (°F)
1	brick (TTW), 4 in.	No Recor...	Generic...	4.00	0.64	17.8	94.1
2	cavity, 3/4 in.	No Recor...	Generic...	0.75	0.69	20.6	93.1
3	cavity, 1 in.	No Recor...	Generic...	1.00	0.98	24.5	91.6
4	rigid ins.,(extru.), 2 in.	No Recor...	Generic...	2.00	10.27	65.4	76.7
5	paper, stand., (8mil)	No Recor...	Generic...	0.01	0.12	65.9	76.5
6	block, 8 in.	No Recor...	Generic...	8.03	1.03	70.0	75.0
	Total or (Layer 0)			15.79	13.73	(15.3)	(95.0)

Appendix G

AACPS School List

Elementary Schools *... Continued*

		Principal	Projected Students	Year Occupied	Grades Served
North Glen (1172) 410-222-6416	615 West Furnace Branch Road Glen Burnie 21061	Julie Little-McVearry	257	1959	PreK-5 ECI
Oak Hill (2172) 410-222-6568	34 Truckhouse Road Severna Park 21146	Deneen Houghton	521	1971	PreK–5
Oakwood (1182) 410-222-6420	330 Oak Manor Drive Glen Burnie 21061	Nancy Knouse	291	1957/•1992	PreK–5 ECI
Odenton (3172) 410-222-6514	1290 Odenton Road Odenton 21113	Tracey Ahern	336	1930/•1961/•1970 •1971/•1972/•1991	K–5
Overlook (1192) 410-222-6585	401 Hampton Road Linthicum 21090	Kristie Battista	205	1955/•1958	K–5
Park (1202) 410-222-6593	201 East 11th Avenue Baltimore 21225	Walter Jackson	369	1943/✦1996	PreK–5
Pasadena (2182) 410-222-6573	401 East Pasadena Road Pasadena 21122	Janis Horn	364	1955/✦2008	K–5
Pershing Hill (3182) (at Meade Heights ES) 410-222-6519	1925 Reece Road Ft. Meade 20755	Tasheka Sellman	165	1960	K–5
Piney Orchard (3242) 410-672-7591	2641 Strawberry Lake Way Odenton 21113	Karen Bailey	536	2000	K–5
Point Pleasant (1212) 410-222-6425	1035 Dumbarton Road Glen Burnie 21060	Lisa Koennel	538	1958 (Building I) 1967 (Building II)	PreK–5
Quarterfield (1232) 410-222-6430	7967 Quarterfield Road Severn 21144	Jennifer Green	452	1969	PreK–5 ECI
Richard Henry Lee (1242) 410-222-6435	400 A Street Glen Burnie 21061	Christopher Wooleyhand	483	1957/✦1972	K–5
Ridgeway (3192) 410-222-6524	1440 Evergreen Road Severn 21144	Vickie Wardell	609	1956/✦1999	K–5
Rippling Woods (3392) 410-222-6440	530 Nolfield Drive Glen Burnie 21061	Gwen Atkinson	667	1974	PreK–5
Riviera Beach (2192) 410-222-6469	8515 Jenkins Road Pasadena 21122	Kathleen Panagopulos	262	1955/•1971/•2001	K–5
Rolling Knolls (4232) 410-222-5820	1985 Valley Road Annapolis 21401	Jane Taylor	434	1963	PreK–5
Seven Oaks (3092) 410-222-0937	1905 Town Center Boulevard Odenton 21113	Lisa Leitholf	606	2007	PreK–5 ECI
Severn (3202) 410-551-6220	838 Reece Road Severn 21144	Veronica Williams	477	1932/•1962/•1985	K–5
Severna Park (2202) 410-222-6577	6 Riggs Avenue Severna Park 21146	Janice Tourre	334	1937/•1964/•1992	K–5
Shady Side (4242) 410-222-1621	4859 Atwell Road Shady Side 20764	Deborah Short	438	1971	K–5
Shipley's Choice (2432) 410-222-3851	310 Governor Stone Parkway Millersville 21108	Rocco Ferretti	431	1988	K–5
Solley (2212) 410-222-6473	7608 Solley Road Glen Burnie 21060	Robert Wagner	596	1937/✦1995	PreK–5
South Shore (3212) 410-222-3865	1376 Fairfield Loop Road Crownsville 21032	Linda Ferrara	240	1957/✦1997	K–5

• *Addition/Renovation* ✦ *Replacement/Total Renovation*

Appendix H

Geothermal Life Cycle Analysis

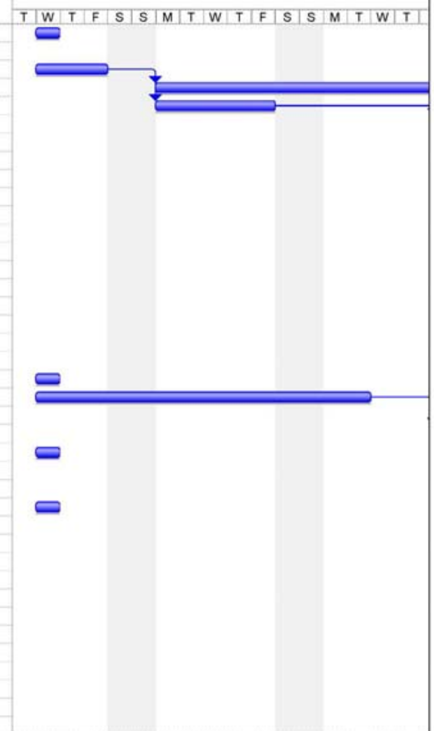
Year	Installation Cost	Energy Cost Escalation	Energy Cost Savings	Maintance Cost	Net Cash Flow	PV Factor	Discounted Cash Flow	PV factor	Discounted Cash Flow
						1%		1.68%	
0	$726,023	0.00%			$ (736,023.00)	1	$ (736,023.00)	1	$ (736,023.00)
1		8.00%	$2,395		$ 2,395.23	0.990	$ 2,371.52	0.9834776	$ 2,355.66
2		8.00%	$ 2,586.85		$ 2,586.85	0.980	$ 2,535.88	0.9672281	$ 2,502.07
3		8.00%	$ 2,793.80		$ 2,793.80	0.971	$ 2,711.63	0.9512472	$ 2,657.59
4		8.00%	$ 3,017.30		$ 3,017.30	0.961	$ 2,899.57	0.9355303	$ 2,822.78
5		8.00%	$ 3,258.69		$ 3,258.69	0.951	$ 3,100.53	0.9200731	$ 2,998.23
6		8.00%	$ 3,519.38		$ 3,519.38	0.942	$ 3,315.42	0.9048712	$ 3,184.59
7		8.00%	$ 3,800.93		$ 3,800.93	0.933	$ 3,545.20	0.8899206	$ 3,382.53
8		8.00%	$ 4,105.01		$ 4,105.01	0.923	$ 3,790.91	0.8752169	$ 3,592.77
9		8.00%	$ 4,433.41		$ 4,433.41	0.914	$ 4,053.64	0.8607562	$ 3,816.08
10		8.00%	$ 4,788.08		$ 4,788.08	0.905	$ 4,334.59	0.8465344	$ 4,053.27
11		8.00%	$ 5,171.13		$ 5,171.13	0.896	$ 4,635.00	0.8325476	$ 4,305.21
12		8.00%	$ 5,584.82		$ 5,584.82	0.887	$ 4,956.24	0.8187919	$ 4,572.80
13		8.00%	$ 6,031.60		$ 6,031.60	0.879	$ 5,299.74	0.8052635	$ 4,857.03
14		8.00%	$ 6,514.13		$ 6,514.13	0.870	$ 5,667.05	0.7919586	$ 5,158.92
15		8.00%	$ 7,035.26		$ 7,035.26	0.861	$ 6,059.82	0.7788735	$ 5,479.58
16		8.00%	$ 7,598.08		$ 7,598.08	0.853	$ 6,479.81	0.7660046	$ 5,820.17
17		8.00%	$ 8,205.93		$ 8,205.93	0.844	$ 6,928.90	0.7533484	$ 6,181.92
18		8.00%	$ 8,862.40		$ 8,862.40	0.836	$ 7,409.12	0.7409012	$ 6,566.17
19		8.00%	$ 9,571.39		$ 9,571.39	0.828	$ 7,922.63	0.7286598	$ 6,974.29
20		8.00%	$ 10,337.11		$ 10,337.11	0.820	$ 8,471.72	0.7166205	$ 7,407.78
21		8.00%	$ 11,164.08		$ 11,164.08	0.811	$ 9,058.87	0.7047802	$ 7,868.22
22		8.00%	$ 12,057.20		$ 12,057.20	0.803	$ 9,686.71	0.6931356	$ 8,357.27
23		8.00%	$ 13,021.78		$ 13,021.78	0.795	$ 10,358.07	0.6816833	$ 8,876.73
24		8.00%	$ 14,063.52		$ 14,063.52	0.788	$ 11,075.95	0.6704202	$ 9,428.47
25		8.00%	$ 15,188.60		$ 15,188.60	0.780	$ 11,843.59	0.6593432	$ 10,014.50
26		8.00%	$ 16,403.69		$ 16,403.69	0.772	$ 12,664.43	0.6484493	$ 10,636.96
27		8.00%	$ 17,715.98		$ 17,715.98	0.764	$ 13,542.17	0.6377353	$ 11,298.11
28		8.00%	$ 19,133.26		$ 19,133.26	0.757	$ 14,480.73	0.6271984	$ 12,000.35
29		8.00%	$ 20,663.92		$ 20,663.92	0.749	$ 15,484.35	0.6168356	$ 12,746.24
30		8.00%	$ 22,317.04		$ 22,317.04	0.742	$ 16,557.52	0.606644	$ 13,538.50
31		8.00%	$ 24,102.40		$ 24,102.40	0.735	$ 17,705.07	0.5966207	$ 14,379.99
32		8.00%	$ 26,030.59		$ 26,030.59	0.727	$ 18,932.16	0.5867631	$ 15,273.79
33		8.00%	$ 28,113.04		$ 28,113.04	0.720	$ 20,244.29	0.5770684	$ 16,223.15

34		8.00%	$ 30,362.08		$ 30,362.08	0.713	$ 21,647.36	0.5675338	$ 17,231.51
35		8.00%	$ 32,791.05		$ 32,791.05	0.706	$ 23,147.67	0.5581568	$ 18,302.55
36		8.00%	$ 35,414.33		$ 35,414.33	0.699	$ 24,751.96	0.5489347	$ 19,440.16
37		8.00%	$ 38,247.48		$ 38,247.48	0.692	$ 26,467.44	0.5398649	$ 20,648.47
38		8.00%	$ 41,307.28		$ 41,307.28	0.685	$ 28,301.82	0.530945	$ 21,931.90
39		8.00%	$ 44,611.86		$ 44,611.86	0.678	$ 30,263.33	0.5221725	$ 23,295.09
40		8.00%	$ 48,180.81		$ 48,180.81	0.672	$ 32,360.79	0.513545	$ 24,743.01
41		8.00%	$ 52,035.28		$ 52,035.28	0.665	$ 34,603.62	0.50506	$ 26,280.94
42		8.00%	$ 56,198.10		$ 56,198.10	0.658	$ 37,001.89	0.4967152	$ 27,914.45
43		8.00%	$ 60,693.95		$ 60,693.95	0.652	$ 39,566.38	0.4885082	$ 29,649.49
44		8.00%	$ 65,549.46		$ 65,549.46	0.645	$ 42,308.60	0.4804369	$ 31,492.38
45		8.00%	$ 70,793.42		$ 70,793.42	0.639	$ 45,240.88	0.4724989	$ 33,449.81
46		8.00%	$ 76,456.89		$ 76,456.89	0.633	$ 48,376.39	0.4646921	$ 35,528.91
47		8.00%	$ 82,573.44		$ 82,573.44	0.626	$ 51,729.21	0.4570142	$ 37,737.24
48		8.00%	$ 89,179.32		$ 89,179.32	0.620	$ 55,314.40	0.4494633	$ 40,082.83
49		8.00%	$ 96,313.66		$ 96,313.66	0.614	$ 59,148.07	0.442037	$ 42,574.21
50		8.00%	$ 104,018.76		$ 104,018.76	0.608	$ 63,247.44	0.4347335	$ 45,220.44
						NPV	$ 205,577.08	NPV	$ (1,167.90)

Appendix I

Pre-Fabricated System Schedule

ID	Task Name	Duration	Start	Finish	Predecessors
1	Sitework Contractor	1 day?	Wed 6/10/09	Wed 6/10/09	
2	Submittals	44 days	Tue 7/7/09	Fri 9/4/09	
3	Stone Construction Entrances	3 days	Wed 6/10/09	Fri 6/12/09	
4	Install Sediment Traps	12 days	Mon 6/15/09	Tue 6/30/09	3
5	Construction Fencing	5 days	Mon 6/15/09	Fri 6/19/09	3
6	Clearing and Grubbing	10 days	Tue 8/11/09	Mon 8/24/09	22,23,4,5
7	Site Demolition	5 days	Tue 8/25/09	Mon 8/31/09	6,22,23
8	Strip Topsoil and Stockpile	5 days	Tue 9/1/09	Mon 9/7/09	7
9	Complete Site Grading	10 days	Tue 9/8/09	Mon 9/21/09	8
10	Building Pad	20 days	Wed 9/16/09	Tue 10/13/09	26
11	Settlement Period at North Side of Pad	15 days	Wed 10/14/09	Tue 11/3/09	10
12	Set Control Hubs and Building Corners	3 days	Wed 10/14/09	Fri 10/16/09	10
13	Install Water Systems and Site Utilities	35 days	Mon 10/19/09	Fri 12/4/09	12
14	Install Temp Roads	10 days	Mon 12/7/09	Fri 12/18/09	13
15	Install Curb, Gutter, and Sidewalk	19 days	Wed 7/14/10	Mon 8/9/10	61
16	Install Asphalt Walks	4 days	Tue 8/10/10	Fri 8/13/10	15
17	Soft Play Areas	5 days	Mon 8/16/10	Fri 8/20/10	16
18	Seeding	3 days	Mon 8/23/10	Wed 8/25/10	17
19	Permanent Fencing	15 days	Thu 8/26/10	Wed 9/15/10	18
20	Abatement Contractor	1 day?	Wed 6/10/09	Wed 6/10/09	
21	Submittals	10 days	Wed 6/10/09	Tue 6/23/09	
22	Phase 1 Building Abatement	19 days	Mon 7/6/09	Thu 7/30/09	21
23	Phase 2 Building Abatement	12 days	Mon 7/20/09	Tue 8/4/09	21
24	Demolition Contractor	1 day?	Wed 6/10/09	Wed 6/10/09	
25	Submittals	10 days	Tue 7/7/09	Mon 7/20/09	
26	Building Demolition	30 days	Wed 8/5/09	Tue 9/15/09	23,25
27	Concrete Contractor	1 day?	Wed 6/10/09	Wed 6/10/09	
28	Submittals and Review	35 days	Tue 8/4/09	Mon 9/21/09	
29	Fabricate and Deliver Rebar	30 days	Wed 9/23/09	Tue 11/3/09	28
30	Area A Concrete Footings	23 days	Mon 11/9/09	Wed 12/9/09	29,10
31	Area A Slab on Grade	24 days	Thu 12/10/09	Tue 1/12/10	30
32	Area A Slabe Cure Period	5 days	Wed 1/13/10	Tue 1/19/10	31,231
33	Area A Slab Repair	7 days	Wed 1/20/10	Thu 1/28/10	32,48,37
34	Area B Concrete Footings	23 days	Wed 11/4/09	Fri 12/4/09	10,11
35	Area B Slab on Grage	15 days	Wed 12/9/09	Tue 12/29/09	34,54
36	Area B Slabe Cure Period	5 days	Wed 12/30/09	Tue 1/5/10	35
37	Area B Slab Repair	6 days	Wed 1/6/10	Wed 1/13/10	36
38	Area B Pour Slab on Deck	17 days	Tue 4/27/10	Wed 5/19/10	69
39	Area C Concrete Footings	24 days	Wed 11/25/09	Mon 12/28/09	10

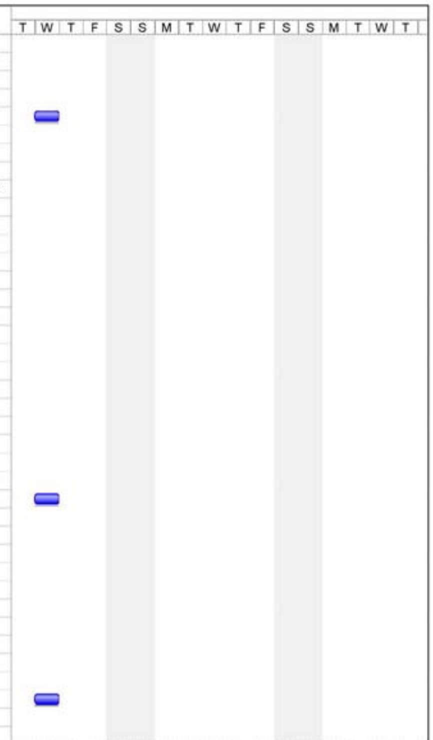


Pershing Hill Elementary School
Tech 2 Detailed Project Schedule

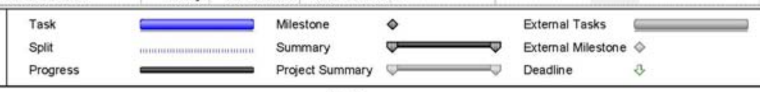
Task | Milestone | External Tasks
Split | Summary | External Milestone
Progress | Project Summary | Deadline

Page 1

ID	Task Name	Duration	Start	Finish	Predecessors
40	Area C Slab on Grage	7 days	Tue 2/9/10	Wed 2/17/10	39,242
41	Area C Slabe Cure Period	5 days	Thu 2/18/10	Wed 2/24/10	40
42	Area C Slab Repair	7 days	Thu 2/25/10	Fri 3/5/10	41
43	Area C Pour Slab on Deck	19 days	Wed 5/19/10	Mon 6/14/10	72,59
44	Masonry Contractor	1 day?	Wed 6/10/09	Wed 6/10/09	
45	Submittals and Review	42 days	Mon 8/3/09	Tue 9/29/09	
46	CMU at Concrete Footings to SOG at Gym/Café	3 days	Mon 10/12/09	Wed 10/14/09	66,45
47	CMU at Concrete Footings to SOG at remaining area A	3 days	Thu 10/15/09	Mon 10/19/09	46,45
48	CMU Bearing Walls at Gym Cafeteria	10 days	Thu 12/24/09	Wed 1/6/10	180,45,46,47,78
49	CMU Bearing walls at remaining area A	12 days	Thu 1/7/10	Fri 1/22/10	48
50	Brick above area A Gym/Café Roof	3 days	Fri 1/29/10	Tue 2/2/10	33,49
51	Wash Brick above area A Gym/Café Roof	3 days	Wed 2/3/10	Fri 2/5/10	50
52	Exterior Brick Veneer Area A	9 days	Mon 2/8/10	Thu 2/18/10	51
53	Exterior Brick washdown Area A	4 days	Fri 2/19/10	Wed 2/24/10	52
54	CMU Wall at Footings to SOG Area B	4 days	Wed 11/4/09	Mon 11/9/09	10,11,45
55	CMU Bearing/Stair Walls Area B	11 days	Mon 1/25/10	Mon 2/8/10	49,45
56	Exterior Brick Veneer Area B	10 days	Tue 5/11/10	Mon 5/24/10	191,52
57	Exterior Brick Washdown Area B	7 days	Tue 5/25/10	Wed 6/2/10	56
58	CMU Wall at Footings to SOG Area C	5 days	Mon 12/21/09	Fri 12/25/09	47,14
59	CMU Bearing/Stair Walls Area C	9 days	Mon 3/8/10	Thu 3/18/10	55,42
60	Exterior Brick Veneer Area C-Media Room	7 days	Thu 6/24/10	Fri 7/2/10	63,43,74
61	Exterior Brick Veneer Area C	7 days	Mon 7/5/10	Tue 7/13/10	132,60
62	Exterior Brick Washdown Area C	6 days	Wed 7/14/10	Wed 7/21/10	61
63	Area C Interior CMU Walls-Foor 1	7 days	Tue 6/15/10	Wed 6/23/10	72,74,43
64	Area C Interior CMU Walls-Foor 2	7 days	Thu 6/24/10	Fri 7/2/10	63
65	Steel Contractor	1 day?	Wed 6/10/09	Wed 6/10/09	
66	Submittals and Review	50 days	Mon 8/3/09	Fri 10/9/09	
67	Fabricate and Deliver	78 days	Mon 10/12/09	Wed 1/27/10	66
68	Area A Roof Joists and Metal Deck	32 days	Fri 2/19/10	Mon 4/5/10	33,52
69	Area B Structural Steel	16 days	Tue 3/30/10	Tue 4/20/10	55
70	Area B Roof Joist and Metal Deck	7 days	Mon 6/7/10	Tue 6/15/10	38,71,69
71	Area B CMU Wall Supports	3 days	Wed 4/21/10	Fri 4/23/10	69
72	Area C Structural Steel	14 days	Thu 4/29/10	Tue 5/18/10	59,42,69
73	Area C Roof Joist and Metal Deck	17 days	Thu 6/24/10	Fri 7/16/10	63,43,70
74	Area C First Floor CMU Wall Supports	3 days	Wed 5/19/10	Fri 5/21/10	72,59
75	Area C Second Floor CMU Wall Supports	3 days	Mon 7/19/10	Wed 7/21/10	73
76	General Works Contractor	1 day?	Wed 6/10/09	Wed 6/10/09	
77	Submittals and Review	56 days	Mon 8/3/09	Mon 10/19/09	
78	Fab and Deliver Bearing Wall HM Frames-Area A	30 days	Tue 10/20/09	Mon 11/30/09	77



Pershing Hill Elementary School
Tech 2 Detailed Project Schedule



Page 2

ID	Task Name	Duration	Start	Finish	Predecessors
79	Fab and Deliver Bearing Wall HM Frames-All Remaining A	1 day?	Tue 12/1/09	Tue 12/1/09	78
80	Area A Architectural Louvers	6 days	Fri 2/26/10	Fri 3/5/10	125,52,77
81	Aluminum Entrance Canopies	10 days	Tue 8/24/10	Mon 9/6/10	
82	Café/Gym Sound blanket and Drywall	13 days	Mon 2/8/10	Wed 2/24/10	51,48
83	Block Fill CMU Walls	12 days	Thu 6/24/10	Fri 7/9/10	49,55,63
84	Area A Paint Prime and First Finish Coat	15 days	Mon 7/12/10	Fri 7/30/10	74,77,83,82
85	Area A Ceiling Grid	7 days	Mon 8/2/10	Tue 8/10/10	84,233,157
86	Area A Paint Second Finish Coat	10 days	Fri 11/5/10	Thu 11/18/10	234,215,84
87	Basketball Backboards in Gym	5 days	Fri 11/19/10	Thu 11/25/10	86
88	Area A Drop Ceiling Tiles	2 days	Tue 12/7/10	Wed 12/8/10	159
89	Area A VCT	7 days	Thu 12/9/10	Fri 12/17/10	88,87
90	Area A Doors and Hardware	6 days	Mon 12/20/10	Mon 12/27/10	89
91	Areas B & C Architectural Louvers	7 days	Mon 8/16/10	Tue 8/24/10	
92	Area B Drywall-Floor 1	12 days	Wed 7/21/10	Thu 8/5/10	142
93	Area B Paint Prime and First Finish Coat-Fl 1	4 days	Fri 8/6/10	Wed 8/11/10	92
94	Area B Ceiling Grid-Fl 1	5 days	Thu 8/12/10	Wed 8/18/10	93,160
95	Area B Paint Second Finish Coat-Fl 1	2 days	Wed 8/25/10	Thu 8/26/10	217,160,93
96	Area B Drop Ceiling Tiles-Fl 1	2 days	Fri 10/8/10	Mon 10/11/10	164
97	Area B VCT-Fl 1	8 days	Tue 10/12/10	Thu 10/21/10	96
98	Area B Doors and Hardware-Fl 1	6 days	Fri 10/22/10	Fri 10/29/10	97
99	Area B Drywall-Floor 2	12 days	Thu 8/12/10	Fri 8/27/10	93,240
100	Area B Paint Prime and First Finish Coat-Fl 2	4 days	Tue 8/31/10	Fri 9/3/10	99,194,238,198
101	Area B Ceiling Grid-Fl 2	3 days	Mon 9/6/10	Wed 9/8/10	100
102	Area B Paint Second Finish Coat-Fl 2	2 days	Tue 9/14/10	Wed 9/15/10	241,161,162
103	Elevator Installation	10 days	Thu 9/16/10	Wed 9/29/10	147,241
104	Area B Drop Ceiling Tiles-Fl 2	2 days	Mon 11/1/10	Tue 11/2/10	98,97
105	Area B VCT-Fl 2	8 days	Wed 11/3/10	Fri 11/12/10	104
106	Area B Doors and Hardware-Fl 2	6 days	Mon 11/15/10	Mon 11/22/10	105,195
107	Area C Drywall-Floor 1	12 days	Fri 9/10/10	Mon 9/27/10	244
108	Area C Paint Prime and First Finish Coat-Fl 1	6 days	Thu 9/30/10	Thu 10/7/10	107,208,100
109	Area C Ceiling Grid-Fl 1	5 days	Fri 10/8/10	Thu 10/14/10	108
110	Area C Paint Second Finish Coat-Fl 1	4 days	Tue 10/12/10	Fri 10/15/10	108,209,247
111	Area C Drop Ceiling Tiles-Fl 1	3 days	Tue 11/23/10	Thu 11/25/10	155,109,205,154
112	Area C VCT-Fl 1	9 days	Fri 11/26/10	Wed 12/8/10	111
113	Area C Doors and Hardware-Fl 1	9 days	Mon 12/13/10	Thu 12/23/10	118
114	Area C Drywall-Floor 2	12 days	Fri 10/1/10	Mon 10/18/10	165
115	Area C Paint Prime and First Finish Coat-Fl 2	4 days	Tue 10/19/10	Fri 10/22/10	114,110
116	Area C Ceiling Grid-Fl 2	5 days	Mon 10/25/10	Fri 10/29/10	115
117	Area C Paint Second Finish Coat-Fl 2	4 days	Wed 11/3/10	Mon 11/8/10	104,166,115

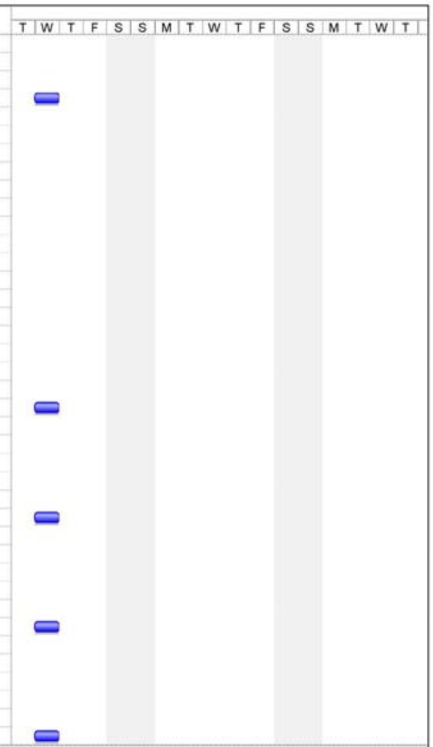
T W T F S S M T W T F S S M T W T

Pershing Hill Elementary School
Tech 2 Detailed Project Schedule

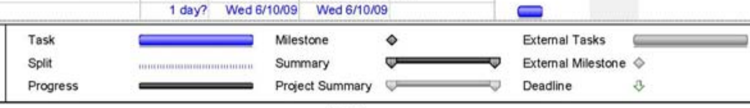
Task — Split — Progress — Milestone — Summary — Project Summary — External Tasks — External Milestone — Deadline

Page 3

ID	Task Name	Duration	Start	Finish	Predecessors
118	Area C Drop Ceiling Tiles-Fl 2	2 days	Thu 12/9/10	Fri 12/10/10	112,116,88,111
119	Area C VCT-Fl 2	7 days	Mon 12/13/10	Tue 12/21/10	118
120	Area C Doors and Hardware-Fl 2	7 days	Fri 12/24/10	Mon 1/3/11	119,113
121	Roofing Contractor	1 day?	Wed 6/10/09	Wed 6/10/09	
122	Submittals	22 days	Tue 9/1/09	Wed 9/30/09	
123	Area A Roof Dry-In/Flashing at Gym/Cafeteria	3 days	Mon 1/25/10	Wed 1/27/10	49,122
124	Complete Roof Ballast at Gym/Café	4 days	Thu 1/28/10	Tue 2/2/10	123,122
125	Area A Roof Dry-In Flashing at Remaining Area A	5 days	Fri 2/19/10	Thu 2/25/10	52,122
126	Complete Roof Ballast at remaining area A	3 days	Fri 2/26/10	Tue 3/2/10	125
127	Fabricate Parapet Coping (All areas)	26 days	Mon 11/8/10	Mon 12/13/10	188,122
128	Area B Roof Dry-In	5 days	Wed 6/16/10	Tue 6/22/10	56,70,122
129	Complete B2 Roof Ballast	2 days	Wed 6/23/10	Thu 6/24/10	128,122
130	Area B Dry in at low area B1 Roof	2 days	Fri 6/25/10	Mon 6/28/10	129,70
131	Complete B1 Roof Ballast	2 days	Tue 6/29/10	Wed 6/30/10	130
132	Area C Roof Dry-In above Media Room	3 days	Thu 6/24/10	Mon 6/28/10	63
133	Comp Roof Ballast above Media Room	3 days	Tue 6/29/10	Thu 7/1/10	132
134	Area C Roof Dry-In at C2 Roof	5 days	Tue 8/3/10	Mon 8/9/10	143,62
135	Area C1 Downspout/Gutter/Facia/Soffit	2 days	Tue 8/3/10	Wed 8/4/10	143
136	Complete C2 Roof Ballast	3 days	Thu 8/5/10	Mon 8/9/10	135
137	Install Parapet Coping	15 days	Tue 12/14/10	Mon 1/3/11	127,81
138	Windows Contractor	1 day?	Wed 6/10/09	Wed 6/10/09	
139	Submittals and Review	38 days	Tue 9/1/09	Thu 10/22/09	
140	Fab and Deliver Exterior Windows	68 days	Fri 10/23/09	Tue 1/26/10	139
141	Area A Exterior Window Installation	6 days	Fri 2/26/10	Fri 3/5/10	125,140
142	Area B Exterior Window Installation	8 days	Fri 6/25/10	Tue 7/6/10	129,128,140
143	Area C Exterior Window Installlation	11 days	Mon 7/19/10	Mon 8/2/10	73,140
144	Kitchen Equipment Contractor	1 day?	Wed 6/10/09	Wed 6/10/09	
145	Submittals and Review	38 days	Tue 9/1/09	Thu 10/22/09	
146	Walk-In Installed	9 days	Fri 5/21/10	Wed 6/2/10	232,179,145
147	Install MEP Hook-Ups	5 days	Mon 8/16/10	Fri 8/20/10	16
148	Install Kitchen Equipment	5 days	Tue 12/28/10	Mon 1/3/11	90
149	Health Department Inspection	5 days	Tue 1/4/11	Mon 1/10/11	148
150	Casework Contractor	1 day?	Wed 6/10/09	Wed 6/10/09	
151	Area A Casework	4 days	Fri 11/19/10	Wed 11/24/10	86,186
152	Area B Basework-Fl 1	10 days	Fri 9/3/10	Thu 9/16/10	95,162,161
153	Area B Basework-Fl 2	10 days	Fri 9/17/10	Thu 9/30/10	102,152
154	Area C Basework-Fl 1	10 days	Tue 10/26/10	Mon 11/8/10	205
155	Area C Basework-Fl 2	10 days	Tue 11/9/10	Mon 11/22/10	117
156	Technical Wiring	1 day?	Wed 6/10/09	Wed 6/10/09	

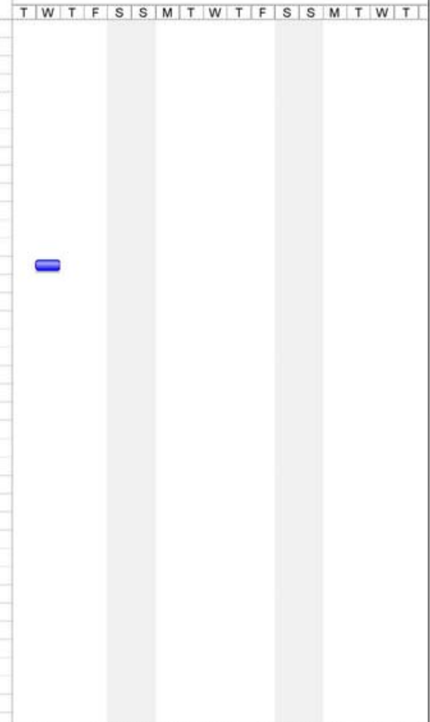


Pershing Hill Elementary School
Tech 2 Detailed Project Schedule



Page 4

ID	Task Name	Duration	Start	Finish	Predecessors
157	Area A Pull Data/ Voice Wiring	7 days	Wed 6/9/10	Thu 6/17/10	233
158	Area A Wall Mounted Devices	4 days	Fri 11/19/10	Wed 11/24/10	86
159	Area A Termination and Testing	7 days	Fri 11/26/10	Mon 12/6/10	158,87,151
160	Area B Pull Data/ Voice Wiring-Fl 1	7 days	Fri 7/9/10	Mon 7/19/10	237
161	Area B Wall Mounted Devices-Fl 1	4 days	Mon 8/30/10	Thu 9/2/10	95,194,220
162	Area B Pull Data/ Voice Wiring-Fl 2	7 days	Wed 8/25/10	Thu 9/2/10	217
163	Area B Wall Mounted Devices-Fl 2	4 days	Thu 9/16/10	Tue 9/21/10	102
164	Area B Termination and Testing	12 days	Wed 9/22/10	Thu 10/7/10	163,199
165	Area C Pull Data/ Voice Wiring-Fl 1	7 days	Tue 9/7/10	Wed 9/15/10	207
166	Area C Wall Mounted Devices-Fl 1	4 days	Tue 10/26/10	Fri 10/29/10	115,167
167	Area C Pull Data/ Voice Wiring-Fl 2	7 days	Fri 10/15/10	Mon 10/25/10	109
168	Area C Wall Mounted Devices-Fl 2	4 days	Wed 11/10/10	Mon 11/15/10	117,210,154
169	Area C Termination and Testing	16 days	Tue 11/16/10	Tue 12/7/10	168
170	Mechanical Contractor	1 day?	Wed 6/10/09	Wed 6/10/09	
171	Rooftop Submittals and Review	43 days	Mon 8/3/09	Wed 9/30/09	
172	Area A Coordinated Drawings	44 days	Mon 8/3/09	Thu 10/1/09	
173	Area B Coordinated Drawings-Fl 1	33 days	Mon 10/5/09	Wed 11/18/09	
174	Area B Coordinated Drawings-Fl 2	33 days	Thu 11/19/09	Mon 1/4/10	173
175	Area C Coordinated Drawings-Fl 1	33 days	Thu 11/19/09	Mon 1/4/10	
176	Area C Coordinated Drawings-Fl 2	33 days	Fri 1/8/10	Tue 2/23/10	
177	Fabricate and Deliver Equipment	54 days	Thu 10/1/09	Tue 12/15/09	171
178	Gas and Domestic Water Services	16 days	Mon 11/9/09	Mon 11/30/09	229
179	Set Gas Meter and Exterior Chiller	5 days	Mon 3/8/10	Fri 3/12/10	183,178,14
180	Area A Underground Plumbing	10 days	Thu 12/10/09	Wed 12/23/09	30
181	Area A Ductwork at Gym/Cafeteria	10 days	Thu 1/28/10	Wed 2/10/10	123
182	Overhead Plumbing Rough-In at Gym/Cafeteria	8 days	Thu 2/11/10	Mon 2/22/10	181
183	Plumbing Insulation in Gym/Cafeteria	9 days	Tue 2/23/10	Fri 3/5/10	182
184	Boiler Room	25 days	Fri 2/26/10	Thu 4/1/10	125
185	Area A Rough-In	19 days	Thu 4/29/10	Tue 5/25/10	141,172
186	Boiler Inspection	10 days	Fri 4/2/10	Thu 4/15/10	184,179
187	Area A OH Mech and Plumbing Insulation	5 days	Wed 5/26/10	Tue 6/1/10	185
188	Area A Final Ceiling Inspection	1 day	Fri 11/5/10	Fri 11/5/10	234,215,146
189	Area A Testing and Balancing	9 days	Tue 12/28/10	Fri 1/7/11	90
190	Area B Underground Plumbing	12 days	Mon 12/7/09	Tue 12/22/09	34
191	Area B Ductwork-Fl 1	14 days	Wed 4/21/10	Mon 5/10/10	69
192	Area B Mech and Plumbing Rough-In Fl 1	16 days	Wed 5/26/10	Wed 6/16/10	185,173
193	Area B Mech and Plumbing Insulation-Fl 1	4 days	Wed 6/23/10	Mon 6/28/10	128,192
194	Area B Final Ceiling Inspection-Fl 1	1 day	Fri 8/27/10	Fri 8/27/10	95
195	Area B Testing and Balancing-Fl 1	8 days	Mon 8/30/10	Wed 9/8/10	194



Pershing Hill Elementary School
Tech 2 Detailed Project Schedule

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

Page 5

ID	Task Name	Duration	Start	Finish	Predecessors
196	Area B Ductwork-Fl 2	14 days	Fri 6/25/10	Wed 7/14/10	129,174
197	Area B Mech and Plumbing Rough-In Fl 2	13 days	Wed 7/7/10	Fri 7/23/10	142,174
198	Area B Mech and Plumbing Insulation-Fl 2	4 days	Mon 7/26/10	Thu 7/29/10	197
199	Area B Final Ceiling Inspection-Fl 2	1 day	Wed 9/15/10	Wed 9/15/10	219,241
200	Area B Testing and Balancing-Fl 2	8 days	Tue 11/23/10	Thu 12/2/10	106,195
201	Area C Underground Plumbing	14 days	Tue 1/5/10	Fri 1/22/10	175,58
202	Area C Ductwork-Fl 1	20 days	Mon 7/19/10	Fri 8/13/10	73,175
203	Area C Mech and Plumbing Rough-In Fl 1	20 days	Wed 7/14/10	Tue 8/10/10	61,175,193
204	Area C Mech and Plumbing Insulation-Fl 1	6 days	Wed 8/11/10	Wed 8/18/10	203
205	Area C Final Ceiling Inspection-Fl 1	1 day	Mon 10/25/10	Mon 10/25/10	221,245,115
206	Area C Testing and Balancing-Fl 1	11 days	Tue 1/11/11	Tue 1/25/11	113,169,200,224
207	Area C Ductwork-Fl 2	16 days	Mon 8/16/10	Mon 9/6/10	202,136,176
208	Area C Mech and Plumbing Rough-In Fl 2	14 days	Fri 9/10/10	Wed 9/29/10	244,176
209	Area C Mech and Plumbing Insulation-Fl 2	5 days	Thu 9/30/10	Wed 10/6/10	208,103
210	Area C Final Ceiling Inspection-Fl 2	1 day	Tue 11/9/10	Tue 11/9/10	117,223,248
211	Area C Testing and Balancing-Fl 2	7 days	Wed 1/26/11	Thu 2/3/11	206,169,120
212	Fire Protection Contractor	1 day?	Wed 6/10/09	Wed 6/10/09	
213	FS Coordinated Drawings	110 days	Wed 11/4/09	Tue 4/6/10	
214	Area A Sprinkler Rough-In	6 days	Wed 6/2/10	Wed 6/9/10	185,187
215	Area A Sprinkler Drops and Heads	8 days	Wed 8/11/10	Fri 8/20/10	85,214
216	Area B Sprinkler Rough-In Fl-1	6 days	Tue 5/11/10	Tue 5/18/10	191
217	Area B Sprinkler Drops and Heads Fl-1	4 days	Thu 8/19/10	Tue 8/24/10	94,198
218	Area B Sprinkler Rough-In Fl-2	6 days	Thu 7/15/10	Thu 7/22/10	196,216
219	Area B Sprinkler Drops and Heads Fl-2	4 days	Thu 9/9/10	Tue 9/14/10	101
220	Area C Sprinkler Rough-In Fl-1	7 days	Tue 8/10/10	Wed 8/18/10	134
221	Area C Sprinkler Drops and Heads Fl-1	4 days	Fri 10/15/10	Wed 10/20/10	109
222	Area C Sprinkler Rough-In Fl-2	6 days	Tue 9/7/10	Tue 9/14/10	207,204
223	Area C Sprinkler Drops and Heads Fl-2	4 days	Mon 11/1/10	Thu 11/4/10	116
224	Install Sprinkler Head Escutcheons at All Areas	5 days	Tue 1/4/11	Mon 1/10/11	223,120
225	Electrical Contractor	1 day?	Wed 6/10/09	Wed 6/10/09	
226	Submittals and Review	42 days	Mon 8/3/09	Tue 9/29/09	
227	Coordinated Drawings	117 days	Mon 10/5/09	Tue 3/16/10	226
228	Fab and Deliver Equipment	65 days	Wed 9/30/09	Tue 12/29/09	226
229	Site Temporary Lighting and Power	15 days	Mon 10/19/09	Fri 11/6/09	12
230	Underslab Electrical at Gym/Cafeteria	3 days	Tue 10/20/09	Thu 10/22/09	47
231	Area A Underslab Electrical	3 days	Wed 12/30/09	Fri 1/1/10	235,177,228,230
232	Area A Electrical Rough-In	21 days	Thu 4/22/10	Thu 5/20/10	126,53,227
233	Area A Pull Power/ Lighting Wiring	13 days	Fri 5/21/10	Tue 6/8/10	232
234	Area A Drop Lights	8 days	Tue 10/26/10	Thu 11/4/10	85,167

T W T F S S M T W T F S S M T W T

Pershing Hill Elementary School
Tech 2 Detailed Project Schedule

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

Page 6

ID	Task Name	Duration	Start	Finish	Predecessors
235	Area B Underslab Electrical	3 days	Wed 12/23/09	Fri 12/25/09	190,230,54
236	Area B Electrical Rough-In Fl-1	12 days	Wed 5/26/10	Thu 6/10/10	185,227
237	Area B Pull Power/ Lighting Wiring Fl 1	6 days	Thu 7/1/10	Thu 7/8/10	193,131,236
238	Area B Drop Lights Fl 1	4 days	Wed 8/25/10	Mon 8/30/10	217
239	Area B Electrical Rough-In Fl-2	9 days	Thu 7/22/10	Tue 8/3/10	142
240	Area B Pull Power/ Lighting Wiring Fl 2	6 days	Wed 8/4/10	Wed 8/11/10	239
241	Area B Drop Lights Fl 2	3 days	Thu 9/9/10	Mon 9/13/10	101,162
242	Area C Underslab Electrical	3 days	Mon 1/25/10	Wed 1/27/10	201
243	Area C Electrical Rough-In Fl-1	14 days	Tue 8/10/10	Fri 8/27/10	75,143,227
244	Area C Pull Power/ Lighting Wiring Fl 1	9 days	Mon 8/30/10	Thu 9/9/10	243
245	Area C Drop Lights Fl 1	5 days	Fri 10/15/10	Thu 10/21/10	109
246	Area C Electrical Rough-In Fl-2	11 days	Fri 9/10/10	Fri 9/24/10	244,227
247	Area C Pull Power/ Lighting Wiring Fl 2	11 days	Mon 9/27/10	Mon 10/11/10	246,222
248	Area C Drop Lights Fl 2	4 days	Mon 11/1/10	Thu 11/4/10	116
249	All Project Team Members	1 day?	Wed 6/10/09	Wed 6/10/09	
250	Final Building Inspection	7 days	Fri 2/4/11	Mon 2/14/11	137,211,195,189,1
251	Obtain Use and Occupancy Permit	1 day	Tue 2/15/11	Tue 2/15/11	250

T W T F S S M T W T F S S M T W T

Pershing Hill Elementary School
Tech 2 Detailed Project Schedule

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

Page 7

Appendix J

LEED Checklist

LEED 2009 for Schools New Construction and Major Renovation

Project Checklist

Project Name

Date

Y	N	?		Sustainable Sites	Possible Points: 24
10	14				
Y			Prereq 1	Construction Activity Pollution Prevention	
Y			Prereq 1	Environmental Site Assessment	
	1		Credit 1	Site Selection	1
4			Credit 2	Development Density and Community Connectivity	4
1			Credit 3	Brownfield Redevelopment	1
	4		Credit 4.1	Alternative Transportation—Public Transportation Access	4
1			Credit 4.2	Alternative Transportation—Bicycle Storage and Changing Rooms	1
	2		Credit 4.3	Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles	2
	2		Credit 4.4	Alternative Transportation—Parking Capacity	2
	1		Credit 5.1	Site Development—Protect or Restore Habitat	1
1			Credit 5.2	Site Development—Maximize Open Space	1
1			Credit 6.1	Stormwater Design—Quantity Control	1
	1		Credit 6.2	Stormwater Design—Quality Control	1
	1		Credit 7.1	Heat Island Effect—Non-roof	1
	1		Credit 7.2	Heat Island Effect—Roof	1
1			Credit 8	Light Pollution Reduction	1
	1		Credit 9	Site Master Plan	1
1			Credit 10	Joint Use of Facilities	1

Y	N	?		Water Efficiency	Possible Points: 11
	11				
Y			Prereq 1	Water Use Reduction—20% Reduction	
	4		Credit 1	Water Efficient Landscaping	2 to 4
	2		Credit 2	Innovative Wastewater Technologies	2
	4		Credit 3	Water Use Reduction	2 to 4
	1		Credit 3	Process Water Use Reduction	1

Y	N	?		Energy and Atmosphere	Possible Points: 33
1	32				
Y			Prereq 1	Fundamental Commissioning of Building Energy Systems	
Y			Prereq 2	Minimum Energy Performance	
Y			Prereq 3	Fundamental Refrigerant Management	
	19		Credit 1	Optimize Energy Performance	1 to 19
	7		Credit 2	On-Site Renewable Energy	1 to 7
	2		Credit 3	Enhanced Commissioning	2
1			Credit 4	Enhanced Refrigerant Management	1
	2		Credit 5	Measurement and Verification	2
	2		Credit 6	Green Power	2

Y	N	?		Materials and Resources	Possible Points: 13
	13				
Y			Prereq 1	Storage and Collection of Recyclables	
	2		Credit 1.1	Building Reuse—Maintain Existing Walls, Floors, and Roof	1 to 2
	1		Credit 1.2	Building Reuse—Maintain 50% of Interior Non-Structural Elements	1
	2		Credit 2	Construction Waste Management	1 to 2

Y	N	?		Materials and Resources, Continued	
	2		Credit 3	Materials Reuse	1 to 2
	2		Credit 4	Recycled Content	1 to 2
	2		Credit 5	Regional Materials	1 to 2
	1		Credit 6	Rapidly Renewable Materials	1
	1		Credit 7	Certified Wood	1

Y	N	?		Indoor Environmental Quality	Possible Points: 19
9	9				
Y			Prereq 1	Minimum Indoor Air Quality Performance	
Y			Prereq 2	Environmental Tobacco Smoke (ETS) Control	
Y			Prereq 3	Minimum Acoustical Performance	
	1		Credit 1	Outdoor Air Delivery Monitoring	1
	1		Credit 2	Increased Ventilation	1
1			Credit 3.1	Construction IAQ Management Plan—During Construction	1
	1		Credit 3.2	Construction IAQ Management Plan—Before Occupancy	1
2	2		Credit 4	Low-Emitting Materials	1 to 4
1			Credit 5	Indoor Chemical and Pollutant Source Control	1
1			Credit 6.1	Controllability of Systems—Lighting	1
1			Credit 6.2	Controllability of Systems—Thermal Comfort	1
1			Credit 7.1	Thermal Comfort—Design	1
	1		Credit 7.2	Thermal Comfort—Verification	1
2			Credit 8.1	Daylight and Views—Daylight	1 to 3
	1		Credit 8.2	Daylight and Views—Views	1
	1		Credit 9	Enhanced Acoustical Performance	1
	1		Credit 10	Mold Prevention	1

Y	N	?		Innovation and Design Process	Possible Points: 6
	6				
	1		Credit 1.1	Innovation in Design: Specific Title	1
	1		Credit 1.2	Innovation in Design: Specific Title	1
	1		Credit 1.3	Innovation in Design: Specific Title	1
	1		Credit 1.4	Innovation in Design: Specific Title	1
	1		Credit 2	LEED Accredited Professional	1
	1		Credit 3	The School as a Teaching Tool	1

Y	N	?		Regional Priority Credits	Possible Points: 4
			Credit 1.1	Regional Priority: Specific Credit	1
			Credit 1.2	Regional Priority: Specific Credit	1
			Credit 1.3	Regional Priority: Specific Credit	1
			Credit 1.4	Regional Priority: Specific Credit	1

Y	N	?		Total	Possible Points: 110
20	85				

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