THE PENNSYLVANIA STATE UNIVERSITY
DEPARTMENT OF ARCHITECTURAL ENGINEERING

BRANDON C. McKEE

CONSTRUCTION
MANAGEMENT

SENIOR THESIS
2007

AMBRIDGE AREA HIGH SCHOOL
AMBRIDGE, PENNSYLVANIA

AMBRIDGE AREA HIGH SCHOOL
AMBRIDGE, PENNSYLVANIA

Project Information
- New high school on site adjacent to existing school in downtown Ambridge, PA
- **Constructed** - September 2005 to September 2007
- **Size** - 245,325 SF
- **Project Cost** - $39.2 Million
- **Project Delivery Method** - Traditional with Multiple Primes

Project Team
- **Owner:** Ambridge Area School District
- **Architect:** Foreman Architects Engineers
- **Construction Management:** Foreman Program and Construction Managers
- **General Contractor:** Kusevich Contracting Inc.

Architectural
- **Building Features** - CAD lab, TV studio, Large Group Instruction space, JROTC target range, gymnasium, & cafeteria
- Exterior walls of red and gray brick, aluminum clad windows, and painted mineral fiber siding
- Bridge to entrance lobby reflective of the American Bridge Co. for which the town is named.

Structural
- **Foundations** - 18” auger cast piles and grade beams.
- **Decking** - 4” on 20 Ga composite deck
- **Slab on Grade** - 4” Thick
- **Framing** - Structural Steel
- 114’ span plate girder to support auditorium balcony
- **Exterior Walls** - Face brick on 8” CMU backup

Electrical, Lighting, & Mechanical
- **Panels** - Five 480V, 17 277/480 V, and 13 480 to 120/208 step down transformers
- 275 kW Diesel generator as backup.
- Typically 277 Volt, Fluorescent T5 and T5HO fixtures
- 19 Air handling units providing 2900-25,715 CFM
- Three gas fired hot water boilers - 6560MBH output
- Two 283 ton chillers
- Fully sprinkled with fire pump providing 750 GPM

Brandon C. McKee **The Pennsylvania State University** **Construction Management**

http://www.arche.psu.edu/thesis/eportfolio/2007/portfolios/bcm159

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EXECUTIVE SUMMARY

This Architectural Engineering senior thesis report comes as a result of a detailed study of the construction of Ambridge Area High School. This report is broken down into four main sections.

The beginning section of this report is to provide a reader with the background information needed to better understand the analyses in further sections of this report. It contains overviews of the project design, delivery, and team, a look at the existing conditions of the site, as well as other project specific details. Most of this information was composed in the fall semester before technical analyses began.

Next is a summary of the research conducted in the spring semester into the barriers public school districts have to building green schools and seeking LEED certification. The intent of this study was to provide schools with a tool to educate students on the benefits and advantages of green construction hoping to make the demand for green construction greater. The results of this study as well as the lesson and tools created are contained in the second section of this report.

The final two sections contain technical analyses whose intents were to provide the Ambridge Area High School with alternative systems and methods to increase end quality and lower construction durations. A redesign of the exterior façade comes first which aims provide a better thermal assembly and lower the construction schedule. The structural impacts of incorporating this system are also part of this analysis. Finally a reconfiguration of the structural steel and façade erection sequence used looks to reduce the overall schedule of the project utilizing 4 dimensional modeling of the Ambridge Area High School.

PROJECT INTRODUCTION

The new Ambridge Area High School (AAHS) is located on Duss Avenue in Ambridge, Pennsylvania. When opened, the 245,325 square foot, three-story high school will replace a facility that is 80 years old located on a site adjacent to the new building.

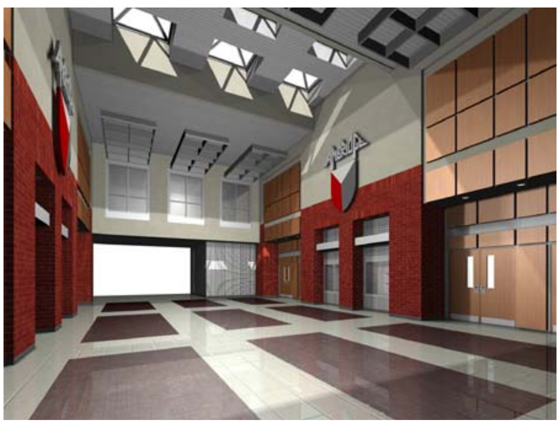
The Ambridge Area School District (AASD), the largest district in Beaver County, Pennsylvania chose new construction over renovation after many studies. Construction began on August 18, 2005 with substantial completion set for August 23, 2007, and students will occupy the building on January 5, 2008. Foreman Program & Construction Managers was chosen as the construction manager of the project and makes the high school the forth project in the district using The Foreman Group as a single source Architect, Engineer, and Construction Manager. The total project cost is just over $42 million and will feature traditional classroom spaces, cafeteria, gymnasium, JROTC target range, and television studio. The Ambridge Area School District hopes the new high school will serve the district for many years to come.

South Elevation Rendering

PROJECT DESIGN OVERVIEW

Architecture:

The new Ambridge Area High School (AAHS) will replace the existing three story brick structure, built in 1928. Efforts to preserve and renovate the school failed when it was declared ineligible for the National Register of Historic Places. It stands as the most distinctive building in the town, also home to Old Economy Village, home of a nineteenth century Christian communal group, in the historic district which retains its original architecture. The new school will mimic the existing one with a massive red brick structure and a steel bridge entrance which pays homage to the steel fabrication operations which built the town in years prior.



Entrance Lobby Rendering

Accessible from the dual story height entrance lobby on the main level, are a one court gymnasium with retractable seating and the auditorium. The basement level holds facilities including a state of the art computer aided drafting (CAD) suite, a television studio, cafeteria, and a JROTC target shooting range, as well as technology education classrooms and the mechanical rooms for the building. In addition to the traditional classrooms, a Large Group Instruction (LGI) space provides teachers with a flexible space capable of seating more students in a university lecture hall type setting.

The new design was met with some resistance from the community, but the project goal is to provide the district with a more efficient building, aiming to improve indoor air quality, accessibility, and technology integration.

Building Codes:

2003 International Building Code

Americans with Disabilities Act

Zoning:

Ambridge, PA for Educational, Assembly, and partial Storage use

Historical Requirements:

Existing Ambridge Area High School

Ambridge, Pennsylvania was incorporated in 1910, named after the American Bridge Company, which started operations there in 1903. Ambridge is situated along the Ohio River, sixteen miles Southwest of Pittsburgh, PA. American Bridge was a consolidation led by J.P. Morgan of the largest steel fabrication and construction companies in the U.S. Notable structures manufactured in Ambridge include: the Sears Tower, Empire State Building, and several U.S. Navy warships during WWII. The population of the town peaked during WWII and has seen a consistent decline since American Bridge ceased operations in 1983. The school's mascot is the Bridger, saluting the industrial heritage of the town. The design intent of Forman Architects and Engineers was to create a new school with some similarities of the existing school and salute the industrial heritage of Ambridge, PA.

Building Envelope:

The exterior walls of Ambridge Area High School consist primarily of face brick, red and gray, to match the school's colors, with a concrete masonry unit backup. Painted mineral fiber siding is used on some elevations in areas between conventional single-hung aluminum windows. Metal grills and screens above the parapet line are used to screen mechanical equipment from view at ground level. The roof over the majority of the building is constructed of tapered insulation over metal roof deck topped with a 60 mil reinforced black EPDM membrane. Stairwells at the corners of the building, and the main entrance are surrounded by glass and aluminum curtain wall and topped with peaked standing seam metal construction supported by trusses.

Structural:

The structural system of Ambridge Area High School is composed of a system of structural steel beams and columns. Structural columns span three floor levels and are supported by pile caps and grade beams both along the building's perimeter and inside the footprint. Grade beams and pile caps are held by 18"auger cast piles to an average depth of 40' to attain sufficient bearing capacity. One unique member supporting the auditorium balcony is a 114' span plate girder weighing 23 tons. Ground level slabs are a 4” slab on grade composed of 3000psi concrete with 6x6 W2.1 x W2.1 welded wire fabric reinforcement. Elevated slabs consist of 4" of 3000psi concrete with 6x6 W1.4x W1.4 welded wire fabric cast over 20 Ga composite steel deck connected to steel members with shear studs.

Structural Steel Erection Complete
Composite Deck Placement Beginning

Electrical:

Power distribution is provided by five 480V and 17 277/480 V panels, and 13 480 to 120/208 step down transformers. Emergency backup power is provided by a 275 kW diesel generator with 1000 gallon storage tank located in the basement mechanical room. Power distribution to the building typically provides duplex receptacles in classrooms and corridors with allowance for computer equipment in east classroom. Spaces are also wired for data with CAT5 Ethernet from various network rooms inside the building, telephone, and cable television. The closed circuit television system allows viewing on televisions in classrooms from outside sources like cable or direct feed from the television studio on the basement level.

Lighting:

Lighting in classrooms is typically pendant fixtures using 277 Volt fluorescent T5HO bulbs. Corridor lighting throughout AAHS is provided by recessed fixtures mounting in the ACT grid using 277 Volt T5 bulbs. The gymnasium is also illuminated using surface mounted fixtures using T5 bulbs with wire guards to protect from abuse. The interior lighting power density for Ambridge Area High School is 0.88 Watts/SF considerably under the allowance of 1.2 Watts/SF.

Mechanical:

Conditioning of interior spaces is handled by 19 Trane air handling units both rooftop and interior mounted providing 2900-25,715 CFM, Three gas fired hot water boilers with a 6560MBH output each, and two 283 ton chillers located in the basement level mechanical room. Distribution of conditioned air is provided through steel sheet metal duct. Exhaust hoods and ductwork vent spaces including the cafeteria, and lab spaces where required. Hot water for plumbing use is provided by the three hot water boilers one acting as a back up unit. A domestic water booster pump provides up to 125 GPM to maintain water pressure throughout the building

Trane rooftop AHU installed

Fire Protection:

AAHS uses a wet pipe sprinkler system with vertical standpipes in stairwells and a free standing fire department Siamese connection located at the main building entrance. Pressure is controlled by a fire pump providing 750 GPM. The fire alarm system provides pull stations with bells and strobes throughout the building.

Conveyance:

Conveyance in AAHS is provided by three hydraulic lift elevators. One freight elevator with a capacity of 4000 pounds travels two stops between the ground level storage space to the kitchen and food service area of the plan. Two passenger elevators on opposite sites of the building provide stops at all floors and a capacity of 2500 pounds. Passenger elevators provide a method of transport for furnishings upon completion of the project as well as passengers to meet ADA compliance.

PROJECT TEAM OVERVIEW

Client:

History

With enrollment on the decline, the AASD chose to consolidate from five elementary schools in the district to three, choosing to either renovate or build, to provide a lower cost alternative to operating from five aging buildings. The new Ambridge Area High School (AAHS) is the newest school to be built in the Ambridge Area School District (AASD). State Street Elementary, finished in August 2001, underwent an extensive renovation and expansion. Economy Elementary and Highland Elementary were new construction and opened in August 2002 and 2004 respectively.

Owner Satisfaction

Since the Ambridge Area High School is the fourth construction project in the Ambridge Area School District in five years, much thought has been placed as to what the expectations of the owner are. In addition to providing a building to serve the community for decades, the project has to also stay within an inflexible budget and schedule. With the design, engineering, project management, and some contractors playing a role in all four district projects, time was saved in adjusting to the acclimation period in dealing with a particular owner. With most parties familiar with the policies and expectations of the Ambridge Area School District, quality could be increased without an increase in input of the team. The construction management agency was a critical step in ensuring the needs of the owner were fulfilled, aiding to minimize change orders and increase overall construction quality. The project schedule was inflexible with substantial completion coming just under four months before occupancy, time allotted for the installation of classroom furnishings and equipment being moved from the existing school set to open doors to students in January 2008.

Project Delivery System:

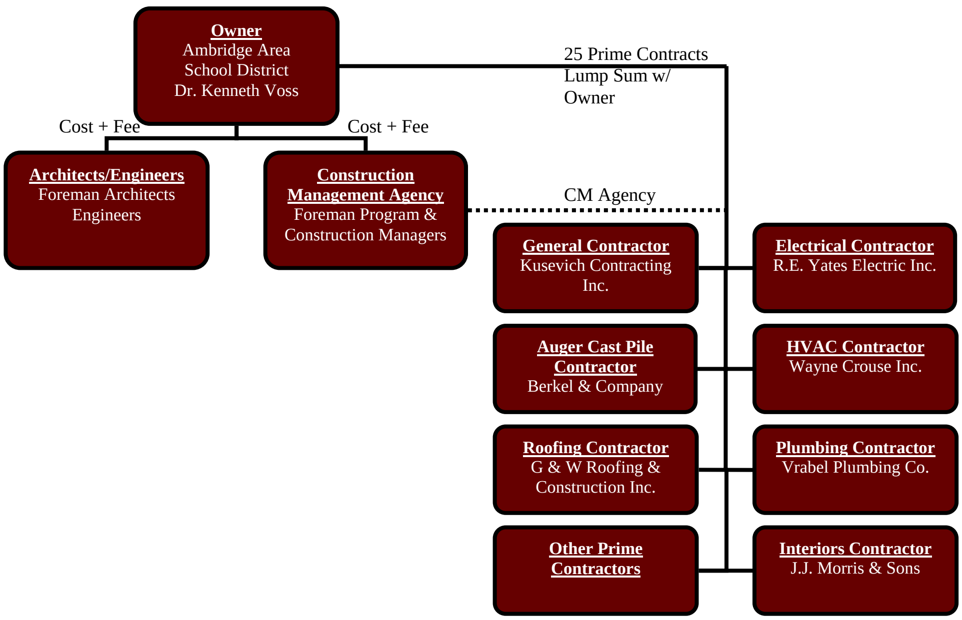
Construction of the new Ambridge Area High School utilized the design-bid-build delivery system with Foreman Architects Engineers (FAE) as the design team, then bid and built using multiple prime contracts to conform to Section 7-751 of the Pennsylvania School Code of 1949, specifying school building projects must have at least four prime contracts: General, Plumbing, HVAC, and Electrical. The Ambridge Area High School used twenty five prime contracts.

1.	General Construction	Kusevich Contracting Inc.
2.	Cast Piles Construction	Berkel & Company Contractors Inc.
3.	Roofing Construction	G & W Roofing & Construction Inc.
4.	Aluminum Entrances/Storefronts	Don's Glass & Mirror
5.	Aluminum Windows	Specified Systems Inc.
6.	Acoustical, Drywall & Plaster	J.J. Morris & Sons
7.	Ceramic and Quarry Tile	J.P. Phillips Inc.
8.	Hardwood Flooring Construction	Wood Floor Designs
9.	Resilient Flooring and Carpeting	Degol Carpet
10.	Visual Display Boards	Polyvision Inc.
11.	Lockers Construction	Lyon Workspace Products
12.	Food Service Equipment	Gateway Kitchen Equipment & Supplies
13.	Vocational Shop Equipment	Allegheny Educational Systems Inc.
14.	Stage Equipment	Pittsburgh Stage Inc.
15.	General Casework Construction	Northeast Interior Systems Inc.
16.	Library Casework	T.F. Nichols Company
17.	Science Casework Construction	Fisher Hamilton LLC
18.	Audience Seating Construction	Naffei Strayer Furnishings Inc.
19.	Bleacher Construction	Dave York Sports Inc.
20.	Grandstands Construction	Dave York Sports Inc.
21.	Fire Protection Construction	Vrabel Plumbing Co. LLC
22.	Plumbing Construction	Vrabel Plumbing Co. LLC
23.	HVAC Construction	Wayne Crouse Inc.
24.	Electrical Construction	R.E. Yates Electric Inc.
25.	Communications Construction	Morocco Electric Inc.

The Ambridge Area School District (AASD) chose Foreman Program and Construction Managers (FPCM) as a construction management agency, to provide on site management and a one point contract between the project and the AASD. Foreman has completed several previous projects in the district including the renovation and expansion of an existing elementary school and the new construction of two elementary schools. Subcontractors were contracted with the owner directly.

The Foreman Group, which encompasses both Forman Architects & Engineers and Foreman Program and Construction Managers, provided a single source entity from conceptual design to finished construction without changing hands. This method helped to ensure constructability issues are considered and handled accordingly in design to reduce potential problems in the field.

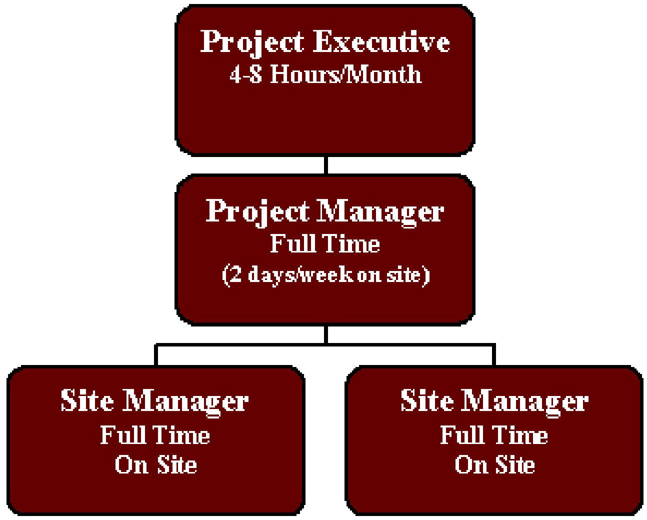
Project Delivery Diagram:



Staffing Plan:

The construction management agency on the Ambridge Area High School organized their operations staff in three levels. At the top level, the Project Executive, spending just four to eight hours per month provided general oversight of the project. The next tier includes the Project Manager, whose part time duties include schedule management, cost tracking, negotiating changes, and correspondence with the owner. Lastly, two full time Site Managers provided on site construction coordination and planning, maintaining and updating the schedule, and safety management. Please refer to the staffing diagram and staff member diagram for more information on the next page.

Staffing Diagram:



Staff Member Distribution

Member	Design	Preconstruction	Mobilization	Structural	Enclosure	Interior Finishes	Punchlist/ Closeout
Foreman Architects/Engineers (FAE)							
Design Team							
Foreman Program & Construction Managers (FPCM)							
Project Executive							
Project Manager							
Site Manager							
Site Manager							

Involvement during this time period

EXISTING CONDITIONS REPORT

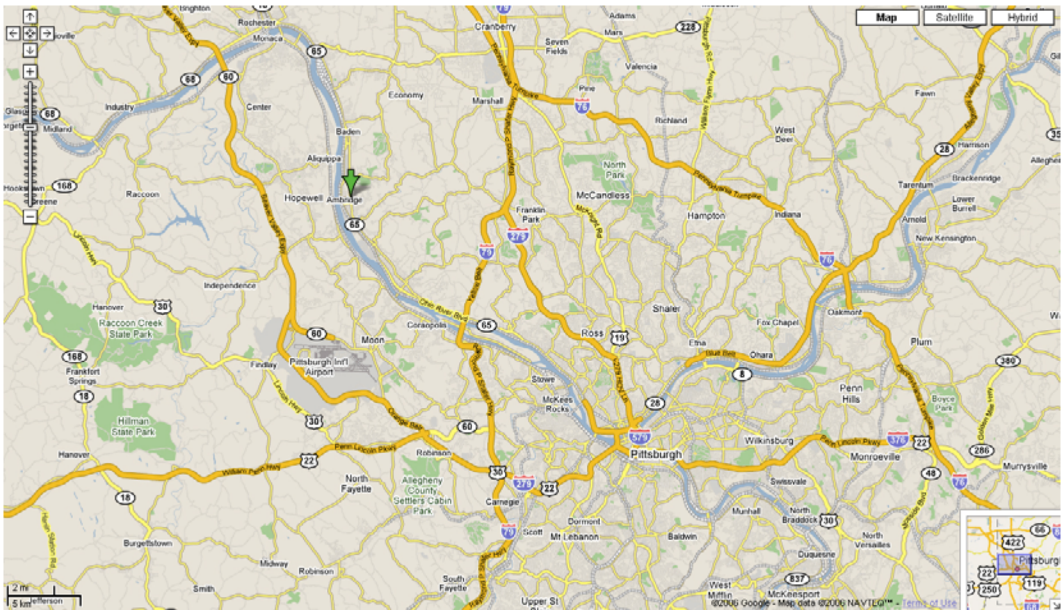
Local Conditions:

Design and construction on Ambridge Area High School were typical of school construction in southwest Pennsylvania. Construction methods in the Pittsburgh area mostly consist of a structural steel frame with slab on deck floors, as does AAHS. The availability of steel and concrete in the area is abundant with several concrete plants in the vicinity. The soil in the project area usually consisted of a level of fill material, usually less than ten feet in depth, followed by layers of siltstone and clay. As Ambridge borders the Ohio River, these soil types are to be expected. Soil was adequate for excavations but forced the use of multiple auger cast piles with pile caps and grade beams to attain proper bearing capacity.

Parking during construction was provided for management personnel in a gravel lot adjacent to the contractor trailers, and accessed from the lower entrance on 11th street (See site plan). Overflow parking was provided on neighboring streets and a park and ride lot within walking distance of the site. Dumpster tipping fees averaged between $400 and $500 with steel waste from construction being recycled, and other waste sent to a landfill.

Vicinity Maps:

Below you fill find two maps depicting the project area. The top map shows Ambridge Area High School in the Pittsburgh, Pennsylvania area, while the bottom one shows the location within the community of Ambridge, PA as well as the location with respect to the existing Ambridge Area High School.



City of Pittsburgh Vicinity Map

Town of Ambridge Vicinity Map

SITE LAYOUT PLANNING

The detailed site plans included in Appendix A detail the site layout during various phases of the project including foundations, superstructure erection, slab on grade, elevated slabs and building enclosure. Access to the site is provided by several gates on both Duss Avenue and 11th Street, with the main delivery entrance for steel via the lower entrance on 11th street. Steel fabrication was done by Sippel Steel in Ambridge, PA, less than 2 miles from the project site. The proximity of the shop location reduced the amount of steel staging areas needed within the site fence, allowing for as many just-in-time deliveries as possible.

Excavation and Foundations:

Auger cast piles were drilled using a pile rig to an average depth of 40’ to attain proper bearing capacity. Excavation for grade beams and pile caps were achieved with hydraulic excavators. A top soil stockpile was used to maintain suitable soil for placement when construction was complete.

Steel Erection:

Erection of structural steel members used a 165 Ton crawler crane in multiple locations, shown in figure 1 erecting the first structural column. Steel erection began adjacent to the retaining wall separating the 1st floor slab on grade and elevated slab area. Using two crane locations, phase one of steel is erected. The installation of the 114’ long, 23 Ton plate girder had to be well planned as the transportation from Sippel required permits and traffic control as the over size truck navigated the streets of Ambridge. The placement of the girder was accomplished with a 200 Ton DEMAG mobile crane. Structural steel topped out on April 4, 2006.

Concrete:

Installation of metal deck followed structural steel erection and was followed with pouring of slabs using a concrete pump in several locations. Several concrete batch plants in close proximity to the project site ensured no shortages of concrete for large pours.

Building Enclosure:

Building enclosure came after completion of structural steel and concrete work with the erection of masons scaffolding around the entire perimeter of the building. Work began on the South elevation adjacent to the main building entrance and proceeded counterclockwise around the footprint ending at the building entrance.

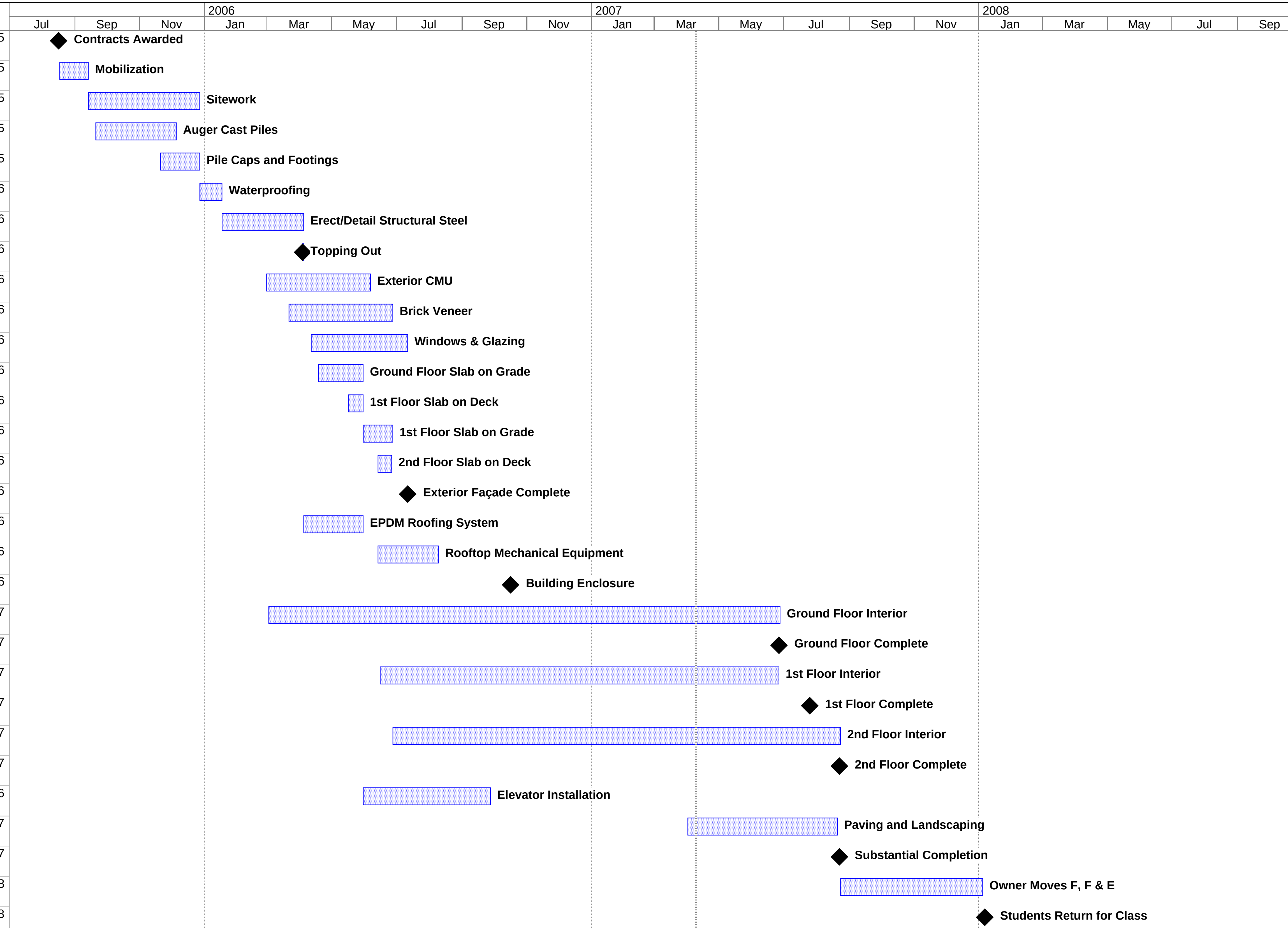
PROJECT LOGISTICS SUMMARY

Detailed Project Schedule:

The Ambridge Area High School schedule is composed of 157 activities. In addition to being broken up into phases of the project, all floor specific work is broken up between the three floors for additional ease. Please refer to the summary schedule on the next page detailing project milestones. A detailed project schedule can be found in Appendix B.

Ambridge Area High School
Summary Schedule

ID	Task Name	Duration	Start	Finish
1	Contracts Awarded	0 days	Wed 8/17/05	Wed 8/17/05
2	Mobilization	19 days	Thu 8/18/05	Tue 9/13/05
3	Sitework	75 days	Wed 9/14/05	Tue 12/27/05
4	Auger Cast Piles	54 days	Wed 9/21/05	Mon 12/5/05
5	Pile Caps and Footings	27 days	Mon 11/21/05	Tue 12/27/05
6	Waterproofing	15 days	Wed 12/28/05	Tue 1/17/06
7	Erect/Detail Structural Steel	55 days	Wed 1/18/06	Tue 4/4/06
8	Topping Out	1 day	Tue 4/4/06	Tue 4/4/06
9	Exterior CMU	70 days	Wed 3/1/06	Tue 6/6/06
10	Brick Veneer	70 days	Wed 3/22/06	Tue 6/27/06
11	Windows & Glazing	65 days	Wed 4/12/06	Tue 7/11/06
12	Ground Floor Slab on Grade	30 days	Wed 4/19/06	Tue 5/30/06
13	1st Floor Slab on Deck	10 days	Wed 5/17/06	Tue 5/30/06
14	1st Floor Slab on Grade	20 days	Wed 5/31/06	Tue 6/27/06
15	2nd Floor Slab on Deck	9 days	Wed 6/14/06	Mon 6/26/06
16	Exterior Façade Complete	0 days	Wed 7/12/06	Wed 7/12/06
17	EPDM Roofing System	40 days	Wed 4/5/06	Tue 5/30/06
18	Rooftop Mechanical Equipment	41 days	Wed 6/14/06	Wed 8/9/06
19	Building Enclosure	0 days	Tue 10/17/06	Tue 10/17/06
20	Ground Floor Interior	344 days	Fri 3/3/06	Wed 6/27/07
21	Ground Floor Complete	0 days	Wed 6/27/07	Wed 6/27/07
22	1st Floor Interior	268 days	Fri 6/16/06	Tue 6/26/07
23	1st Floor Complete	0 days	Thu 7/26/07	Thu 7/26/07
24	2nd Floor Interior	302 days	Wed 6/28/06	Thu 8/23/07
25	2nd Floor Complete	0 days	Thu 8/23/07	Thu 8/23/07
26	Elevator Installation	86 days	Wed 5/31/06	Wed 9/27/06
27	Paving and Landscaping	101 days	Mon 4/2/07	Mon 8/20/07
28	Substantial Completion	0 days	Thu 8/23/07	Thu 8/23/07
29	Owner Moves F, F & E	96 days	Fri 8/24/07	Fri 1/4/08
30	Students Return for Class	0 days	Mon 1/7/08	Mon 1/7/08



Project: Summary Schedule.mpp
Date: Mon 4/9/07

Task		Progress		Summary		External Tasks	
Split		Milestone		Project Summary		External Milestone	

Deadline

Brandon C. McKee
Construction Management

Project Estimate Summary:

The table below summarizes the project estimate including general conditions, foundations, structure, and façade items. All data was obtained using R.S. Means 2005 with necessary location factors included.

Estimate Summary		
Division Name	**% of Total**	**Cost**
General Conditions	1.56%	$604,436
Concrete		
Piles	2.16%	$840,704
Grade Beams/Pile Caps	1.33%	$517,821
Slab on Grade	0.46%	$179,057
Elevated Slabs	0.63%	$243,013
Masonry		
Brick & CMU	5.50%	$2,137,162
Metals		
Structural Members	6.42%	$2,495,695
Metal Deck	0.97%	$375,598
Doors and Windows		
Windows	0.34%	$130,289
Curtainwall	0.46%	$180,243
Total Project Cost	**100.00%**	**$38,846,057**

AAHS used twenty six prime contracts, the table below details the amounts of these contracts which add to the total construction cost of $38,846,057. The design and construction management fees were estimated as industry standard for a school project and bring total project cost to approximately $42,730,663. Please note items including superstructure and building façade are included in the general contractor's prime contract.

AAHS Actual Prime Contract Cost Schedule			
Package	**Contract #**	**Total Cost ($)**	**SF Cost ($)**
General Construction	401	$14,933,500.00	-
Cast Piles Construction	402	$1,025,600.00	-
Roofing Construction	403	$1,194,500.00	-
Aluminum Entrances and Storefronts	404	$528,189.00	-
Aluminum Windows	405	$159,200.00	-
Acoustical, Drywall & Plaster	406	$3,869,686.00	-
Ceramic and Quarry Tile	407	$734,029.00	-
Hardwood Flooring Construction	408	$149,274.00	-
Resilient Flooring and Carpeting	409	$509,700.00	-
Visual Display Boards	410	$91,858.00	-
Lockers Construction	411	$156,600.00	-
Food Service Equipment	412	$509,159.00	-
Vocational Shop Equipment	413	$235,000.00	-
Stage Equipment	414	$193,377.00	-
General Casework Construction	415	$553,800.00	-
Library Casework	416	$102,800.00	-
Science Casework Construction	417	$247,700.00	-
Audience Seating Construction	418	$127,000.00	-
Bleacher Construction	419	$96,520.00	-
Grandstands Construction	420	$755,000.00	-
Fire Protection Construction	422	$453,400.00	-
Plumbing Construction	423	$1,895,000.00	-
HVAC Construction	424	$5,376,500.00	-
Electrical Construction	425	$3,837,000.00	-
Communications Construction	426	$1,111,665.00	-
Contract Total:		**$38,846,057.00**	**$158.35 / SF**
AE FEE (Industry Range - 5-8%)	6.50%	$2,524,994.00	10.29/SF
CM FEE (Industry Range - 2-5%)	3.50%	$1,359,612.00	5.54/SF
Project Total (Approximate):		**$42,730,663.00**	**174.18/SF**

General Conditions Estimate:

With the contract arrangement being multiple prime with a CM, the general conditions costs are shared by more than one contractor. Gathering actual general conditions costs was difficult. Please find the estimate using items listed in the temporary facilities portion of the specification for use by the Construction Manager, in the table below. R.S. Means was utilized to gather the unit costs used in this estimate.

Category	Quantity	Unit	Duration (Months)	Unit Price	Cost / Month ($)	Total Cost ($)
Staffing						
Project Management	1	EA	24	-	$6,700	$160,800
Site Supervisors	2	EA	24	-	$6,200	$297,600
Site Items						
Office Trailers	1	EA	24	-	$554	$13,296
Mobilize Trailers	1	EA	-	$5,000	-	$5,000
Schedule	1	EA	-	$3,000	-	$3,000
Project Sign	2	EA	-	$300	-	$600
Temporary Fence	2,200	LF	24	$20	-	$44,000
Gravel Parking Area	2,500	SY	-	$9	-	$22,500
Temporary Toilets	6	EA	24	-	$185	$26,640
Site Survey	1	EA	-	$4,000	-	$4,000
Silt Fence	2,200	LF	-	$3	$275	$6,600
Temp. Utilities						
Electric	1	EA	24	-	$300	$7,200
Water	1	EA	24	-	$250	$6,000
Telephone	1	EA	24	-	$300	$7,200

Totals	**$25,185**	**$604,436**

ANALYSIS 1 - DEPTH

Green Design in Public Schools

Problem

The new Ambridge Area High School will replace a building over 80 years old and will certainly provide the school district with lower operating costs over the existing building. LEED® certification and inclusion of green design principles were not utilized on this and many other public school projects because of the desire to provide low first costs to satisfy tax-paying citizens and the lack of knowledge and understanding of the LEED® system. Aiming at providing a public school district with a green and efficient building at a minimal additional cost is of major concern, as these buildings tend to have extensive operation and maintenance costs over time.

Goal

The goal of this research is to explore what knowledge school districts have on green building and the LEED® rating system. By speaking to members of industry, public school districts, and people from outside the engineering and construction fields, I hope to develop a method to educate on the benefits that green construction has to offer in terms of reduction of energy and operation costs, indoor air quality and occupant comfort, and reduction in negative effects on the environment. I feel that the incorporation of lessons on green building in high school class situations would marry well with the science and technology class curriculums. By teaching students at this level, hopefully green construction will become more of a topic of discussion outside the design and construction industries.

Methodology

1. Develop a list of interview questions to be asked to public school owners with recent or ongoing school construction projects.
2. Develop a list of interview questions to be asked to design professionals including architects and contractors involved in new school design and construction.
3. Identify and interview various owners, contractors and architects of school construction projects both determining the knowledge of LEED®.
4. Gather information on benefits and advantages of LEED and green construction related to schools
5. Construct a lesson to introduce and educate students on LEED® design and construction.

Tools

The following are tables of questions to be asked to public school owners (Table 1) and designers of public school projects (Table 2) during an interview. The list will be revised and expanded if necessary before conducting research.

1. U.S. Green Building Council Website (www.usgbc.org)
2. Other Green Building Websites
3. LEED® Green Building Rating System for New Construction & Major Renovations (LEED®-NC Version 2.1)
4. Penn State Architectural Engineering Faculty
5. Questionnaires to public school districts and industry professionals
6. Personal conversations with high school science and technology teachers
7. Microsoft PowerPoint

Research

To identify the knowledge of building green and LEED rated schools, questionnaires were distributed to members of industry including architects, engineers, and contractors both who have been involved on a LEED rated project and those who have had no direct involvement in a green building project. Also, questionnaires were distributed to public school districts to gather their opinions and understanding on green construction and LEED. For summaries of the contents of questionnaires please refer to Appendix C. Countless references were collected from both online and print sources on the benefits of green building as well as case study school projects to adapt the green principles better to the intended audience.

Findings

As a result of research into the barriers public school districts have to building LEED rated schools, the primary barrier is lack of information about the LEED rating system, its benefits, and the level of knowledge of industry members who are suggesting LEED to school districts and owners. Industry members indicated that green building and LEED certification are sometimes a hard item to sell to an owner of a project because of the perceived additional costs and lack of knowledge on actual benefits and potential payback periods on investment. Public school districts indicate that projects on already tight budgets leave little funding available to incorporate technologies with added up front costs regardless of their potential cost savings over time. Districts also indicate if they had a better understanding on actual benefits of green building and LEED, they would be more apt to seek more information and possibly seek LEED certification.

Problem 1

Lack of Knowledge:

While information about green buildings and LEED is everywhere in publications as well on the internet, there is no one source of information which is directed toward educating the general public and more specifically high school aged students on the benefits of building green and LEED rated schools. In most cases in the Pittsburgh, Pennsylvania area as is the case in the Ambridge Area School District, enrollment in schools has seen a steady decline in past decades leaving many school districts to consolidate schools within their own districts as well as combine with neighboring districts to lower operation costs attributed with their school buildings. Many of the school buildings in this area are nearing their intended lifespan and need much renovation work to provide students with classrooms with adequate indoor air quality, natural light and technological features. While many school districts opt to renovate to maintain existing structures and locations of schools, others choose to build new buildings in adjacent or new locations to the existing school.

Nine states in the U.S. require LEED certification on public projects while twenty three states have legislation pending or require LEED on projects in certain areas or from specific government agencies. Green building and LEED are catching on as more case studies and analyzes are conducted demonstrating their positive affects with energy efficiency, indoor air quality, and reduction in environmental effects. Educating the public on the benefits of LEED and providing one location for information is the goal of this research.

Problem 2

Cost:

The second barrier to incorporating LEED rated construction and design is the perception or an increased cost associated with Green Construction. Pennsylvania Governor Edward G. Rendell formed the Governor Green Council of Pennsylvania aiming to stimulate green design and construction across Pennsylvania. The council offers grants for school districts that plan to build green. For the 2005-2006 school year, $200,000 in grants were provided to seven school districts to help offset any additional costs to achieving LEED certification. This funding is offered on a first come first served basis annually with applications being accepted starting July 1. While other means of funding and incentives are available, there have been LEED certified schools constructed with little or no additional cost and short payback periods on additional initial investment.

Tools:

As a result of research, a lesson was developed to serve as an educational tool for use in high schools - either science or technology classes to introduce and discuss the topic of LEED and Green Building. As this is a relatively new topic, it is known that many students have little or no knowledge about Green Building. Green construction has many advantages including, reduced energy use, and reduced maintenance costs, improving indoor air quality, reducing instances of cold and allergies, increasing productivity, reducing the negative effects on the environment. This information can be incorporated into a number of class types including science, technology, and a college like EGEE 101 at Penn state - Energy and the

Environment. I feel the integration and introduction of this material in high schools will allow discussions to occur at home with parents and other adults spreading information about green building like wildfire. Green building has seen slow incorporation in several areas of industry due to lack of knowledge and lack of understanding.

Green school design addresses:

- Classroom acoustics
- Master planning
- Indoor air quality
- Mold prevention
- Energy efficiency
- Water conservation

As high school students are years or even months away from joining the workforce or beginning a college education, what better a time to plant the seed of energy awareness and sustainable building. This course will hope to educate about the advantages of green building in addition to promoting a more energy conscious society in their own homes. With earth day and Arbor Day being large in schools this lecture may also be incorporated on an annual basis in April or taught as an additional lecture in any science or technology based course.

Ideally, this lecture would be contained in a stand alone course promoting topics in the energy and environmental realm. Additional topics may include: Alternative fuel vehicles, geothermal energy, solar energy, hydroelectric power production, straw bale construction, fuel cells, energy efficient homes, and promoting alternative transportation.

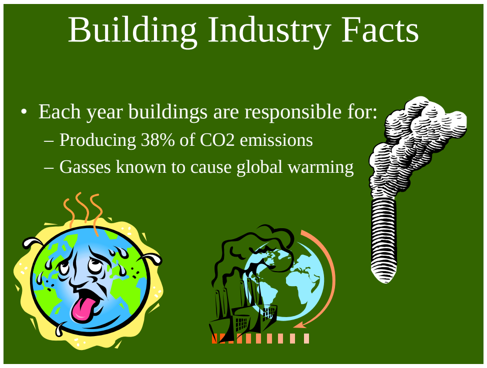
Lecture

The lecture itself is formatted into three main points. The first section includes facts about the building industry, followed by an introduction into green buildings and the LEED rating system, and finally the energy benefits of green schools presented through potential cost savings if the students' school were green.

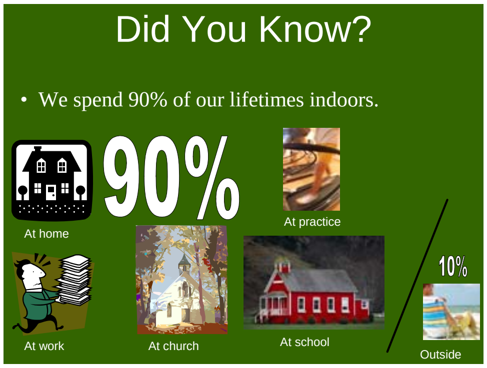
While the first section of this lecture contains many facts about the true damage the building and construction industry poses to the environment and the users of the building, it is very important that students realize the true extent of this damage should they have any hope in showing interest in a possible solution.

Annually the building industry is responsible for producing over 38% of the CO2 emissions known to cause global warming. As global warming has become a hot topic in the past few years, it has primarily been blamed on the burning of fossil fuels such as automobile and truck use. Buildings are responsible for consuming 69.7% of all electricity generated and 39.4% of all energy produced each year. As far as waste produced, it was found the average human creates approximately 2.8 pounds of waste per day with the building industry responsible for 136 million tons of waste being sent to landfills each year, as well as consuming 12% of the fresh water on earth.

Facts on the damaging effects buildings pose on their inhabitants are also included in this section. It may come as a surprise to some students but humans spend approximately 90% of their lifetimes in buildings, and indoor air quality may be 2-5 times worse than outdoor air quality. An estimated 14 million school days are missed each year as a result of asthma with indoor air pollutants such as dust and mold triggering asthma attacks. These facts are contained in the lecture slides in a simple format with graphics to reinforce the topic. Two sample slides from this section of the lecture are shown below.



Sample slide from Building Facts



Sample slide from Building Facts

After concluding the background information session of the lecture, a student led, teacher monitored discussion is conducted requiring students to develop potential solutions to the problems buildings pose, and tasking them to think of potential problems their specific school poses to occupants and the environment.

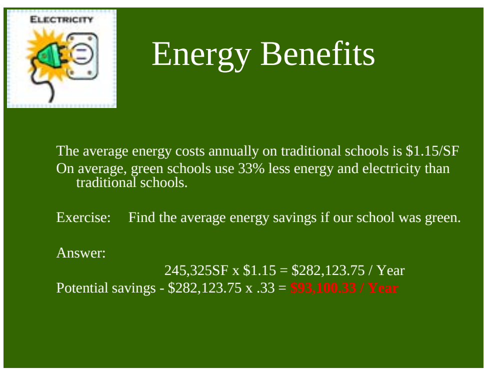
The next section of the lecture contains information on the principles of green building and an introduction of the LEED rating system for new construction. While this lecture is not meant to provide students with all the knowledge needed to design or evaluate a green building, it does educate on the six main areas to earn points, and the four levels of LEED certification a project can achieve. This information will allow students to have a basic understanding of the LEED system and allow them to look at case study school projects with the background knowledge necessary to understand the benefits.

A short look into what makes a building green is followed by facts on the progression of green building and LEED throughout the country. Included in this section are the U.S. government agencies requiring LEED construction on projects, a look into states across the country who have LEED legislature in place or pending, and some high profile green projects in the Pittsburgh, Pennsylvania area, which students may have seen, heard about or even been into without knowing the background information on green construction and LEED.

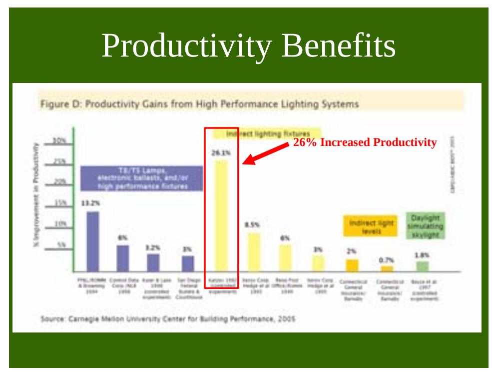
Sample slide from LEED Introduction

Sample slide from LEED Introduction

The final section details benefits of green construction and LEED. The information is presented through a potential cost savings study of the students' school if it were green. First is energy and electricity savings, followed by water consumption savings and finally the benefit the students' school would have on reducing air pollution. For the Ambridge Area High School, using approximate figures would have the potential to save $93,100 annually on electricity, $4,710 on water use and prevent 585,000 pounds of CO2 and 1,200 pounds of nitrogen dioxide from being emitted annually. Also included from a Carnegie Mellon University study were potential health benefits in the way of reduction of asthma and allergy symptoms and the potential increase in productivity of building occupants. The information was presented in this way to demonstrate to students the difference their individual school could make on the environment and through savings their school district could use toward teachers or textbooks rather than increased energy bills.



Sample slide from Green Benefits



Sample slide from Green Benefits

Following the green benefits section of the lecture, two LEED school case studies are discussed allowing students to see the practical implications of the topics they have just learned. The two schools, Fossil Ridge High School, a LEED Silver project built at no additional cost, and Clearview Elementary School in Hanover, Pennsylvania, a LEED Gold project built at an additional 2.15% initial cost are studied in terms of their environmental benefits as well as their energy saving aspects. Several other case studies may be incorporated, such as those listed on the next page.

USGBC LEED Rated School Case Studies					
Project Name	**Owner**	**City**	**State**	**Country**	**LEED**
Third Creek Elementary School	Irdell-Statesville Schools-Admin Offices	Statesville	NC	US	Gold
Clearview Elementary School	Hanover Public School District	Hanover	PA	US	Gold
IslandWood: A School in the Woods	IslandWood	Bainbridge Is.	WA	US	Gold
John M. Langston High School Continuation	Arlington Public Schools, Arlington County	Arlington	VA	US	Silver
Clackamas High School	Clackamas High School	Clackamas	OR	US	Silver
Felician Sisters Convent and School Renovation	Felician Sisters of Pennsylvania	Coraopolis	PA	US	Gold
Baca/Dlo'ay azhi Community School	Baca Community School	Prewitt	NM	US	Certified
Fossile Ridge High School	Poudre School District	Fort Collins	CO	US	Silver

A final discussion allows groups to brainstorm for ideas to spread awareness of the benefits and advantages of LEED schools and construction. This information can be incorporated into the group project portion of the program.

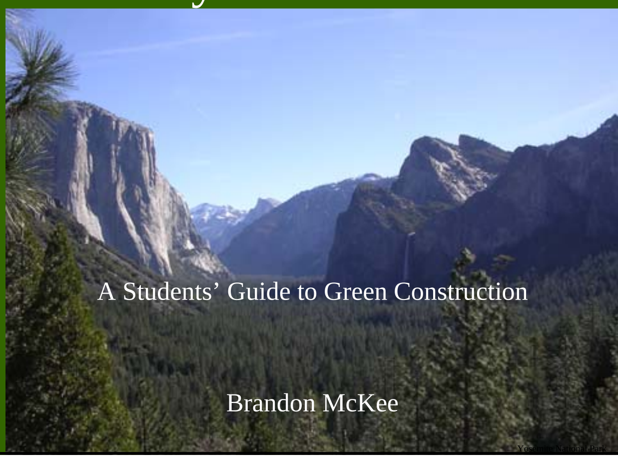
In addition to the lecture with PowerPoint slides, an instructor may utilize the additional tools created as part of this research. A WebQuest type quiz was produced requiring students to show their knowledge on the topics of green construction and LEED. This method requires students to use the websites listed on the quiz to research and complete the questions. This method allows students to gather information on their own from green and LEED websites possibly increasing their interest in the topic and allowing them to read and learn material outside of the classroom lecture setting. This WebQuest quiz can be found on the next page.

A final group project can be utilized to reinforce this topic should interest and time permit. The project developed allows students to form groups and develop a method to spread awareness of the benefits and advantages of green construction and LEED. In groups, students are required to use various methods such as performing a skit, developing a poster or flyer, or producing a short movie to showcase the advantages of building green. The activity allows students to collaborate together and use their own creativity and talents to convey the intended message to the audience.

Conclusion

After conducting research and developing a lesson for use in high school class settings, it is believed that LEED and green building is a concept that is progressing its way through the construction industry. The two main barriers school districts were found to hold to building green were lack of knowledge and understanding and the perceived additional costs to build green. This lecture will hopefully aim to educate school aged students of the benefits and advantages and possibly cultivate discussions at home between parents and relatives or other adult figures in a students' life. It is felt that this age group of students will be most likely to take action and strive to request and require LEED legislation be put in place or at least incorporate some green ideals into construction of school or other building projects should they be in any capacity to do so.

Why Build Green?

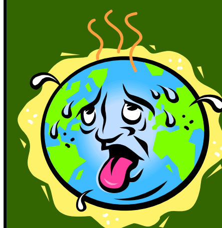


A Students' Guide to Green Construction

Brandon McKee

Building Industry Facts

- Each year buildings are responsible for:
  - Producing 38% of CO2 emissions
  - Gasses known to cause global warming



Building Industry Facts

- Each year buildings are responsible for:

  Consuming 67.9% of electricity

  & 39.4% of all energy produced

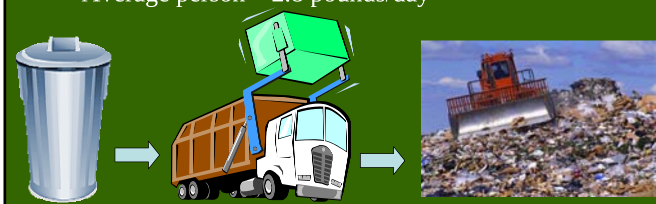
Building Industry Facts

- Each year buildings are responsible for:

  Draining 12% of fresh water

Building Industry Facts

- Each year buildings are responsible for:
  - Sending 136 million tons of waste to landfills
  - Only 20 – 30% of waste is recycled
  - Average person – 2.8 pounds/day



Did You Know?

- We spend 90% of our lifetimes indoors.

Did You Know?

- Indoor air pollution may be 2-5 times higher and sometimes 100 times higher than outdoors.
  - Pollution indoors includes : cleaning products, dust, personal care products, furniture and building materials

Did You Know?

- Asthma is the most common childhood chronic disease.
  - Over 6 million children have asthma
  - An estimated 14 million school days are missed because of asthma
  - Indoor pollution can trigger asthma – dust, mold, dander & secondhand smoke

Discussion #1

- With your group, discuss potential solutions to these problems caused by buildings.
  - Air pollution
  - Energy consumption
  - Draining fresh water
  - Filling landfills
  - Indoor air pollution
- Can you think of any issues this school has with these topics?

Green Building and LEED

- U.S. Green Building Council (USGBC) – non profit, based in Washington D.C.
- Committee based
- Organized to promote:
  - Sustainable site planning
  - Indoor environmental quality
  - Energy efficiency
  - Conservation of materials
  - Safeguarding water
- Created the Leadership in Energy & Environmental Design (LEED) rating system

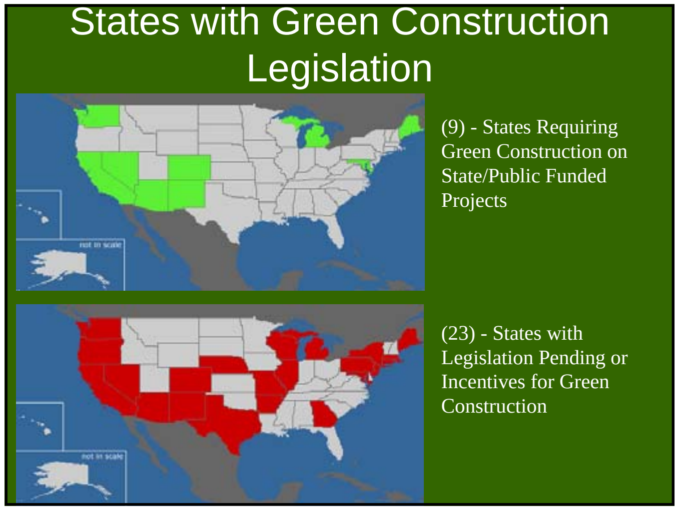
LEED

- LEED was created to:
  - Define what is "Green"
  - Provide a standard of measurement
  - Prevent false green claims
  - Raise consumer awareness
  - Stimulate competition in the marketplace

LEED® Rating System

- Four levels of certification
  - Certified (26-32 points)
  - Silver (33-38 points)
  - Gold (39-51 points)
  - Platinum (52-69 points)
- 6 categories worth 69 points
  - Sustainable Sites (14 points)
  - Water Efficiency (5)
  - Energy & Atmosphere (17)
  - Materials & Resources (13)
  - Indoor Environmental Quality (15)
  - Innovation & Design Process (5)


What Makes a Building Green?
• Incorporating elements into design such as:
– Waterless or low flow plumbing fixtures
– Certified Wood Products – Eliminates clear cutting
– High efficiency lighting fixtures
– Low VOC emitting paints and products
– Close to public/alternative transportation
– Day lighting
– Solar panels – photovoltaic cells
Yukon™ Waterless Urinal - Waterless CO
Photovoltaic (Solar) cells
Low/ no VOC paints from Sherman-Williams
Bicycle racks to reduce automobile use

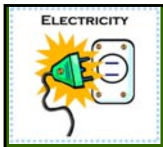

States with Green Construction Legislation
(9) - States Requiring Green Construction on State/Public Funded Projects
(23) - States with Legislation Pending or Incentives for Green Construction


Government Required LEED
The following government agencies require LEED construction
• General Services Administration (GSA)
• U.S. Air Force
• U.S. Navy
• U.S. Army Corps of Engineers
• Department of State
• Department of Energy (DOE)
• Environmental Protection Agency (EPA)
U.S. GREEN BUILDING COUNCIL


Green Buildings in Our Area
Gold
David L. Lawrence Convention Center
Silver
PNC Firstside Center
Gold
Pittsburgh Glass Center
Silver
REI – South Side

Benefits of Green Schools

- Green schools can:
  - Use less energy
  - Use less water
  - Reduce greenhouse gas emissions
  - Provide more natural light and ventilation
  - Improve student and teacher health
  - Improve test scores and productivity
  - Teach you, parents and teachers about a healthier environment



Energy Benefits

The average energy costs annually on traditional schools is $1.15/SF
On average, green schools use 33% less energy and electricity than traditional schools.

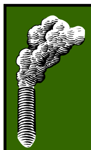
Exercise: Find the average energy savings if our school was green.

Answer:
245,325SF x $1.15 = $282,123.75 / Year
Potential savings - $282,123.75 x .33 = **$93,100.33 / Year**

Water Saving Benefits

The average water costs annually on traditional schools is $0.06 / SF
On average, green schools use 32% less water and create less waste water than traditional schools.

Exercise: Find the average water savings if our school was green.
Answer:
245,325SF x $0.06 = $14,719.50 / Year
Potential savings - $14,719.50 x .33 = **$4,710.24 / Year**

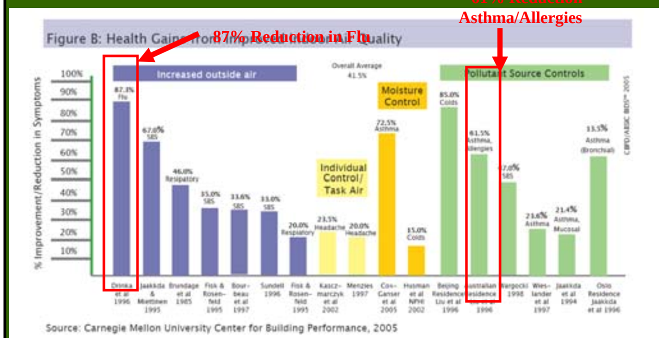


Air Pollution Benefits

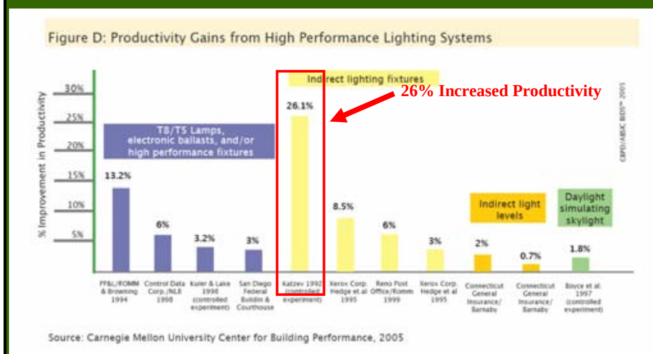
It is estimated than a green school could reduce the following emissions annually.

- 585,000 pounds of carbon dioxide (CO_2)
- 1,300 pounds of sulfur dioxide (SO_2)
- 1,200 pounds of nitrogen dioxide (NO_2)

Health Benefits



Productivity Benefits



Green Saving Summary

Green schools costs on average 2% more initially than traditional schools.

Let us look at the payback period on this investment from only water and energy savings on our school.

Cost to go green $38,846,057 x 0.02 = $776,921

Energy savings $93,100 / Year
Water savings $4,710 / Year
$97,810 / Year total potential savings

Payback period $776,921 / $97,810 annually = 7.9 Years

Green School Case Studies

- Case Study #1 - Fossil Ridge High School - Fort Collins, Colorado
- Case Study #2 - Clearview Elementary School - Hanover, Pennsylvania

Case Study #1
Fossil Ridge High School
Fort Collins, Colorado

State of the art 290,000 SF for 1,800 students

$0 - Additional cost for LEED

60% - More energy efficient

$11,500 - Annual water savings

75% - Waste recycled

Low VOC furnishings

LEED Silver 2005

Case Study #2
Clearview Elementary School
Hanover, Pennsylvania

43,600 SF for 350 students

2.15% - Additional cost for LEED

7 Year – Payback period from energy savings alone

Uses 40% less energy than traditional school

50% of building materials recycled

LEED Gold 2002

Discussion #2

- With your group, discuss how to spread awareness about the benefits and advantages of LEED and building green schools and buildings.

Green Schools Video

- The following video was produced to spread awareness and create interest in high performance green schools.

Better Places to Learn

Sources

Information contained in the preceding presentation was compiled from the following sources.

- Build It Green www.builditgreen.org
- Governors Green Council www.gggc.state.pa.us
- Green Building Pages www.greenbuildingpages.com
- Greening America's Schools by Gregory Kats www.cap-e.com
- U.S. Environmental Protection Agency www.epa.gov
- U.S. Department of Energy www.energy.gov
- United States Green Building Council (USGBC) www.usgbc.org

LEED® & GREEN BUILDING WEBQUEST

Names: ____________________________

____

Date: ____________________________

Objective: Alone or with a partner use the websites listed below and information from the in class lecture to complete the following questions about Green Building and LEED®.

Websites:

www.gggc.state.pa.us/gggc

www.usgbc.org

http://www.cap-e.com/ewebeditpro/items/O59F11233.pdf

www.energy.gov

www.epa.gov

Questions:

1. Green schools save on average $_______________ per year – That's enough to buy _______ new computers or buy __________new textbooks for students.

2. Buildings are responsible for producing _______% of CO2 emissions each year, known to cause global warming.

3. The ________rating system is the nationally accepted benchmark for design construction and operation of high performance green buildings.

4. The four levels of LEED certification are __________, __________, __________, and __________.

5. Buildings drain ______% of the fresh water we need to drink and survive each year.

6. We as humans spend about ____% of our lives indoors at school, work, home, practice or church.

7. The average person creates _____pounds of waste in the form of garbage each day, while the building industry is responsible for sending ___________ tons of waste to landfills each year.

8. The building industry currently recycles between ____ and _____% of construction waste and demolition debris on average.

9. The LEED rating system allows building projects to earn points in six categories. They are ______________, _________________, ______________, _________________,______________, and _________________.

10. LEED stands for what? _____________________________________

11. List three reasons why the LEED rating system was developed. ________________, ______________, _________________

12. An estimated ____________ school days are missed each year as a result of asthma.

13. Currently there are ______ states requiring LEED certification on publicly funded building projects.

14. The average green school uses _______less energy and electricity than traditional schools.

15. Green schools cost on average _____% more initially than traditional ones with an expected payback period of around ______ years.

16. In the Carnegie Mellon University study, green principles were found to reduce asthma and allergies up to _______% and increase productivity by up to _____%.

17. Building one green school could keep _______pounds of CO2 and ________ pounds of nitrogen dioxide from being emitted annually.

18. The average green school uses _____% less water than traditional schools do.

19. The state of the art Fossil Ridge High School in the case study cost the school district $__________ additional to go green.

20. The Clearview Elementary School uses _____% less energy than a traditional elementary school of its size.

LEED® & GREEN BUILDING

GROUP PROJECT

Names: ___________________________

____

____

____

Date: ___________________________

Objective: In groups of 2-4 students, create a plan to spread awareness of green building and LEED® to people outside of this class. You may use any of the following formats to spread awareness or create your own. Remember, to be as creative as possible and use your personal interests to adapt the information to your audience.

- Create an article to be printed in the school newspaper
- Perform a short skit to the school or other group of people
- Develop a poster or flyer to educate and list potential places to display it
- Create a short movie staring yourself or others
- Create a board game to teach and entertain
- Create your own!

Potential topics can include but are not limited to:

- LEED® rating system
- Benefits of building green
    - Environmental
    - Health
    - Energy savings
- Ways your audience can help

ANALYSIS 2 – STRUCTURAL/MECHANICAL BREATH

Precast Architectural Brick façade in place of Norman brick and CMU.

Problem

The current façade design of the Ambridge Area High School uses the traditional construction of concrete masonry unit (CMU) backup with insulation and Norman face brick as the finish façade layer. Masonry work on the project took months to complete, and with masonry scaffolding surrounding the entire footprint of the building during that time, slows other enclosure trades who must wait for masonry work to finish (See detail below). In addition, finish trades inside the building may begin earlier if enclosure comes earlier.

Goal

The goal of this analysis is to examine whether replacing the current composite wall system with an architectural precast panelized system will help to reduce the construction schedule and allow building enclosure at an earlier date, as well as increase the thermal resistance of the wall system, aiming to lower heating and cooling costs. Structural impacts with incorporating this system will also be studied. Since the panels are built in a controlled environment, less material will be wasted and the quality of the finished product will hopefully be higher.

Mason scaffolding around building footprint.

Methodology

1. Determine quantity of brick and concrete masonry units to be replaced.
2. Select a panelized system to replace the brick.
3. Contact the manufacturer to determine potential cost and erection time savings.
4. Compare the two systems in terms of costs and schedule.
5. Examine R-values of both systems and estimate savings in mechanical loads.
6. Analyze structural impacts of precast system on the existing foundation system.
7. Assemble the data.

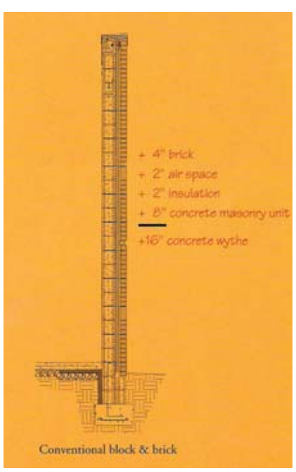
Tools

1. R.S. Means 2006 Edition
2. High Concrete – Precast Manufacturer
3. Penn State Architectural Engineering Faculty
4. ASHRAE Handbook of Fundamentals
5. AISC Steel Construction Manual
6. ACI Concrete Design Code

Outcome

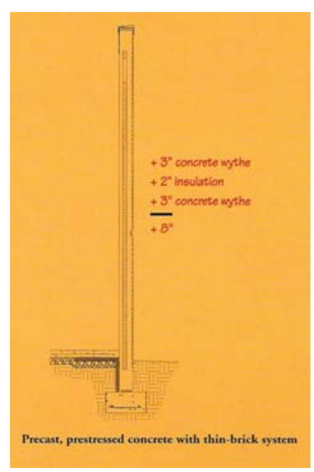
Several precast façade systems were available to replace the CMU and brick system. The insulated precast concrete panel with inset brick from High Concrete was chosen because of its similarities in structure to the existing façade. The interior finish of classrooms with the existing system is CMU with a sill constructed across the rooms. Appearance to the interior will be unchanged. Advantages of using architectural precast products include quicker erection speed, and less wasted materials and higher potential quality over brick because precast panels are produced in controlled environments. The diagrams below detail the construction of the existing CMU and brick wall assembly and the chosen precast concrete panel system.

After analyzing the two systems in terms of cost, schedule, mechanical loads and structural loads, Architectural precast panels are viewed to be equal or better than the original system in all aspects except initial cost. The following sections detail each area of analysis and the outcome of each.



Left – Conventional wall assembly section

Right – Precast concrete wall assembly section.



Looking at the façade as built and the alternative as detailed below, the proposed system of precast panels would be stacked horizontally and have inset brick from the factory to match the desired aesthetics of the façade as originally designed.

Conventional brick and CMU façade as built with area of precast panel outlined.

Exploded view of precast panelized wall system for area detailed at left.

Cost Impacts

As is the case with most precast assemblies, they have a higher initial cost attributed to offsite labor during the manufacturing process. Cost increases can be offset by faster erection speeds and an increase in quality of the finished product. The High Concrete precast system chosen to replace the existing CMU and Norman brick façade is approximately 67% more in first cost as compared to the original façade system. Please refer to the tables below for more information pertaining to costs.

Wall System Cost Comparison

System	Quantity	Unit	Cost/SF	Total Cost	
CMU & Brick	59541	SF	$35.89	$2,137,162.00	
Precast	59541	SF	$60.00	$3,572,460.00	
				$1,435,298.00	67.16% INCREASE

Assumptions:
Using actual schedule of values for masonry construction
Cost for precast panels quoted from High Concrete

Schedule Impacts

Precast assemblies are traditionally quicker to erect than are traditional composite masonry walls. Actual durations for masonry work were derived from the actual project schedule and lasted 85 days. This duration was double-checked against the R.S. Means production rate for this wall system to ensure a reasonable crew size of eleven masons. Production rates for precast panels came from a representative at High Concrete. After comparing the duration of the two systems, it is clear that precast wall panels have the potential to reduce the masonry schedule on Ambridge Area High School by just over 63 days. This early installation allows building enclosure to come earlier than originally scheduled and can reduce the overall project schedule by this same amount. With a reduction of the overall project schedule, the General Conditions costs could be reduced by $75,474 over 12 weeks as listed in General Conditions estimate. To contrast this potential schedule savings, High Concrete indicated the typical lead-time for the precast panels would be 6-8 weeks before delivery to site to allow for shop drawings and fabrication. Increased planning would need to occur to ensure timely delivery and erection of the precast façade. Please refer to the table below for direct schedule comparison between the two systems.

Wall System Schedule Comparison

System	Quantity	Unit	Production	Hours	Days	
CMU & Brick	59541	SF	0.125	676.60	85.0	
High Concrete	59541	SF	2,720	175.1	21.9	
Insulated Panels	180	Panels	8 Panels/Day			
					-63.1	**DECREASE**

Assumptions:
8 hour work day
Masonry crew - 11 Masons to meet actual schedule of 85 days
Masonry productivity rate from R.S. Means
Masonry price from actual project schedule of values
Precast production rate from High Concrete - 8 panels/day - 2720 SF/day

Mechanical Impacts

Possible impacts on the mechanical system may come from differing insulation values of wall systems. The wall system with the highest R value or its resistance to heat transfer will be the better system for the heating and cooling loads in the building. The following table calculates the R-value of each system respective to each component in the assembly.

R-Value Computation

Wall Type	Component	Thickness (in)	Unit R-Value	Unit	Total R-Value
Traditional Brick					
	Outside Air Film	∞	0.17	EA	0.17
	Norman Brick	4	0.09625	In	0.385
	Extruded Polystyrene Insul.	2	5.00	In	10
	Air Cavity	2	1.68	In	3.36
	Concrete Masonry Unit	8	0.1025	In	0.82
	Inside Air Film	∞	0.68	EA	0.68
			Total R-Value	hr-sf-F/ BTU	**15.415**
		16"	**U - Value**	BTU/ hr-sf-F	**0.065**

R-Value Computation

Wall Type	Component	Thickness (in)	Unit R-Value	Unit	Total R-Value
Precast Panel					
	Outside Air Film	∞	0.17	EA	0.17
	Concrete Panel	3	0.8	In	2.4
	Extruded Polystyrene Insul.	2	5.00	In	10
	Concrete Panel	3	0.8	In	2.4
	Inside Air Film	∞	0.68	EA	0.68
			Total R-Value	hr-sf-F/ BTU	**15.65**
		8"	**U - Value**	BTU/ hr-sf-F	**0.064**

After calculating a wall systems R-value, it is possible to compute any changes in the mechanical load requirements for the building.

Summer - Cooling Loads

To	86
Ti	70
ΔT	16

Winter -Heating Loads

To	15
Ti	70
ΔT	55

Heat Transfer Equation

$qx = (T\infty 1 - T\infty 2) * A / Rt$ or $qx = \Delta T * A * U$

Summer Heat Gain

System	Area (SF)	U-Value	ΔT	Heat Gain	
			F°	(BTU/hr)	(Tons)
Traditional Brick	59541	0.065	16	61800.58	5.15
Precast Panel	59541	0.064	16	60872.59	5.07

Difference	**0.08**	
Chiller Load	**283.1**	**TON**
Difference %	**0.027%**	

Winter Heat Loss

System	Area (SF)	U-Value	ΔT	Heat Loss
			F°	(BTU/hr)
Traditional Brick	59541	0.065	55	212439.51
Precast Panel	59541	0.064	55	209249.52

Difference	3189.99	
Boiler Load	6560000	**BTU**
Difference %	0.049%	

Mechanical Impacts (continued)

With a higher thermal resistance R-Value than the traditional system by less than .2 hr-sf-F/ BTU, using precast has little to no effect on the overall thermal resistance of the exterior facade. The reduction in winter heat loss and summer head gain are both less than 1%, and thus will not positively or negatively benefit the loads to mechanical equipment. No necessary resizing of mechanical equipment is necessary to incorporate a precast façade.

Structural Impacts

The proposed insulated precast wall system manufactured by High Concrete would be an 8" thick precast panel with thin brick to match the masonry alternative. Panels would have a 3-inch exterior layer of concrete with brick inset, a 2-inch layer of extruded polystyrene insulation, and a 3-inch final layer of concrete. The concrete mix would consist of a 5000psi mix with welded wire fabric reinforcement throughout, #5 rebar at the panel perimeter and surrounding any openings, and a pre-stressed steel tendon at the central axis. Required slots for mounting and lifting would be cast as a part of the original product for timely erection in the field.

The original system of CMU back up and Norman brick was designed to pass gravity loads into the perimeter grade beams transferring them into the ground through the auger cast piles. The system is provided lateral support by the structural steel system at perimeter beam and column locations. The gross square footage of area to be replaced is 59,541 square feet. Using a weight of 45 pounds per square foot for this assembly, the total weight of the system is approximately 2,679,345 pounds or 1340 tons. The insulated precast system also is tied to the structure laterally and passes all gravity loads into the foundation system. The precast system weighs approximately two times that of the original assembly at 100 pounds per square foot totaling 2977 tons.

Wall System Structural Comparison

System	Quantity SF	Weight PSF	Total Weight (lb)	Total Weight (Ton)	
CMU & Brick	59541	45	2679345	1339.67	
Precast	59541	100	5954100	2977.05	
			DIFFERENCE	**1637.38**	**INCREASE**

As a result of this significant increase in load for the exterior wall system, an analysis of the existing foundation system was necessary to ensure it provides adequate bearing capacity. The grade beam carrying the load of the wall system was analyzed as a simply supported doubly reinforced concrete beam.

Structural Impacts (continued)

After further analysis of the existing foundation system, the grade beams were found to be sufficiently designed to carry the additional loads created by using the precast wall system. The table below shows a summary of the calculations performed to analyze grade beam A. For a complete set of calculations, please refer to Appendix D.

Load Analysis Summary for Grade Beam A

f'c= 4000 psi		
fy= 60 ksi		
w = 4800 plf		
Vu = 72 kips	ΦVn = 14.94 kips	F.S. = 4.8
Mu = 540 k-ft	ΦMn = 340.69 k-ft	F.S. = 1.59

Lateral load effects from wind associated with changing the wall system are unchanged as the system is still attached in the same way to the structural steel and has the same area.

Conclusion

After examining the results of this analysis, the panelized precast façade system meets or exceeds the existing façade system in all aspects but cost. Using precast has the potential to save 63 days on the schedule, remove the builders scaffolding from around the building footprint, allowing less congestion of trades and building enclosure to occur at an earlier date. Precast panels usually have a higher finish quality as they are constructed in a controlled environment and the imperfections of labor in the field are reduced.

While the precast system weighs slightly double that of the existing system, the existing foundation system is adequate to support this increased load. Lateral support is provided by the structural steel system as was the CMU and brick system requiring no added structural pieces. Mechanical impacts of incorporating precast are negligible as the heat loss and gain between the systems differ by less than 0.05%.

Cost is the only disadvantage to incorporating the precast system, which costs $3,572,460. This equates to an increase in cost of slightly over 67% from the existing system. When set against the overall cost of the project, using precast would show an increase of roughly 3.7%. Allowing other trades to perform work at an earlier date has the potential to reduce general conditions costs should substantial completion come an earlier date.

Using architectural precast to replace the CMU and brick façade for the Ambridge Area High School is a feasible alternative and could prove to be beneficial to the overall quality of the finished project.

ANALYSIS 3

Structural Steel Erection Sequencing

Problem

The construction schedule of the AAHS was 24 months when the project was bid. Delays in funding delayed the project start date. Since the new school is being built adjacent to the existing school, no temporary classrooms were necessary, but the old school is slated for demolition following occupancy of the new school. Substantial completion is scheduled for August 23, 2007, with classes starting in the building, after the holiday break on January 8, 2008 in the new building.

Goal

The goal of this technical analysis is to examine the possibility of reducing or accelerating the schedule by several months focusing primarily on the steel erection sequence paired with the use of a precast façade system. With the existing brick façade system, brick work begins after topping out of structural steel. By allowing façade construction to begin as structural steel is still occurring will allow earlier turnover to occur possibly at the start of the school year to reduce impact on students. This would allow the Ambridge Area School District to move furnishings and equipment over the summer break period and allow students to begin the 2007-2008 school year in the new facility rather than transitioning to the new building half way through the year. The schedule reduction should decrease general conditions costs without forcing increased costs in structural steel work.

Methodology

1. Examine steel erection and façade sequencing used on project
2. Determine alternative sequence to reduce schedule
3. Model alternative sequence using 4-D modeling
4. Compute any additional costs attributed to overlapping façade and steel erection
5. Compute reduced general conditions costs after reduction in overall schedule

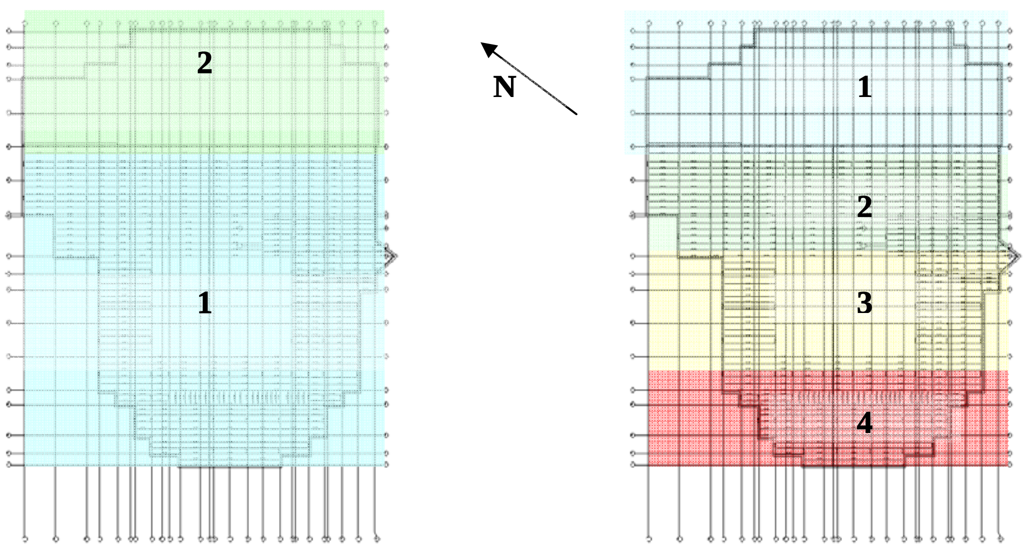
Figure 2 - Steel erection underway

Tools

1. Penn State Architectural Engineering Faculty
2. Autodesk Revit Structure 4
3. Navisworks (4 Dimensional Model Capability)
4. High Concrete - precast manufacturer

Outcome

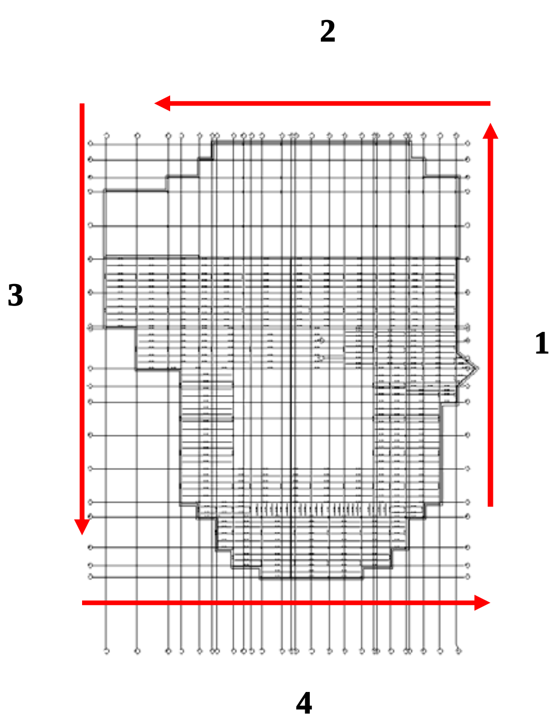
The steel erection sequence used on the Ambridge Area School District by the structural steel erector called for steel erection to begin at column line N and move west to column line A completing the East section of the building last from column line N to S. The proposed sequence would begin at the East side of the footprint at column line S and proceed in four phases to column lines N, K, E and A respectively, as shown below.



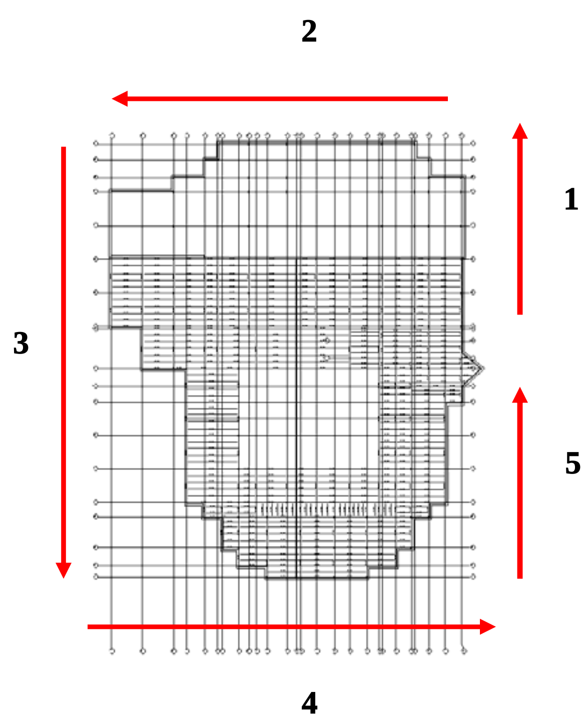
Erection Sequence Used

Proposed Sequence

Currently, the exterior façade of CMU and brick begins after structural steel is completely erected and detailing of structural steel and deck has begun. Using this alternative sequence of steel erection would allow precast panels to begin erection on the South elevation of the building after phase 3 of the structural steel erection has completed. The current sequence begins on the South façade and progresses around the building footprint in a counterclockwise rotation ending back on the South façade. The proposed sequence begins on the south façade adjacent to the main building entrance on column line K. This sequence also progresses around the footprint in the same fashion as the existing sequence but is concurrent to steel erection underway in phase 4. This method allows for an earlier exterior façade completion date and less congestion around the site because of the elimination of mason's scaffolding around the entire footprint of the building. Please refer to Appendix A for project specific site plans.



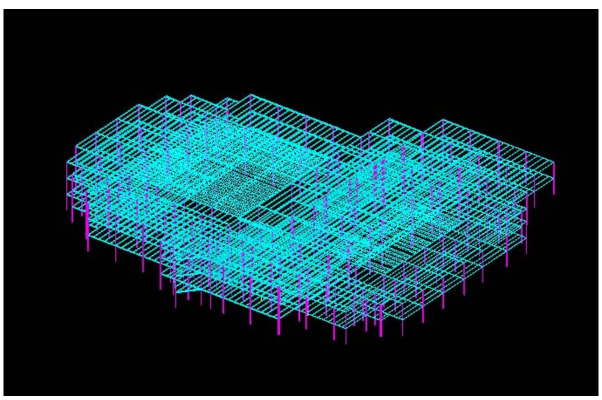
Facade Sequence Used



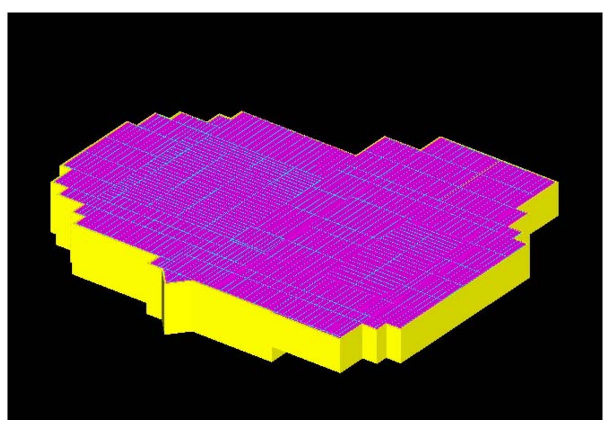
Facade Sequence Proposed

Schedule Impacts

After modeling and analyzing the structural steel and façade erection sequence used on the Ambridge Area High School, it is evident that while the alternative sequence chosen has the potential to expedite the time when the exterior façade is complete. Currently the exterior façade completion date is 7/12/2006 with building enclosure occurring on 10/7/2006. The revised sequence allows for exterior façade completion to occur approximately one month earlier on 6/13/2006 but as the EPDM roof schedule ties to the topping out of structural steel and this duration remains unchanged regardless of the sequence chosen, building enclosure still occurs on 10/17/2006. While other trades are able to complete work on the exterior façade after the completion of precast erection, and interior trades on lower floors may begin to put work in place which is not moisture sensitive, moisture sensitive activities are driven by the completion of the roofing system. As a result, no reduction in the overall project schedule occurs because the timeline for building enclosure remains unchanged.



Navisworks model of steel erection complete



Navisworks model of steel and façade work complete

Cost Impacts

As initially intended this analysis would provide a reduction in the overall project schedule and thus provide savings in the way of a refund to the owner of general conditions costs per month saved on the total duration. The impact on the structural steel erector and precast erector are minimal, and additional costs to erect in this sequence adds no additional costs to the project as the durations for each portion of the project remain the same, require no additional materials, and crane usage remains unchanged.

Conclusion

As a result of looking into the re-sequencing of the façade and steel erection on the Ambridge Area High School, it can be seen that the proposed sequence provides an exterior façade completion date approximately one month prior to that of the existing sequence. This duration can be attributed to the speed differential of erection of precast panels over that of traditional masonry construction. The costs attributed to changing to the proposed sequence and the cost savings by doing so are minimal if any because overall scope of work and overall project schedule are unaffected.

With these factors in mind, it is recommended that the Ambridge Area High School use this method of sequencing on the structural steel and façade areas of the project to provide an exterior façade completion date earlier thus allowing other trades to begin work in a less congested environment.

SUMMARY AND CONCLUSIONS

Three analyses were performed on the Ambridge Area High School. The analyses focused on the incorporation of green building techniques and construction schedule reduction.

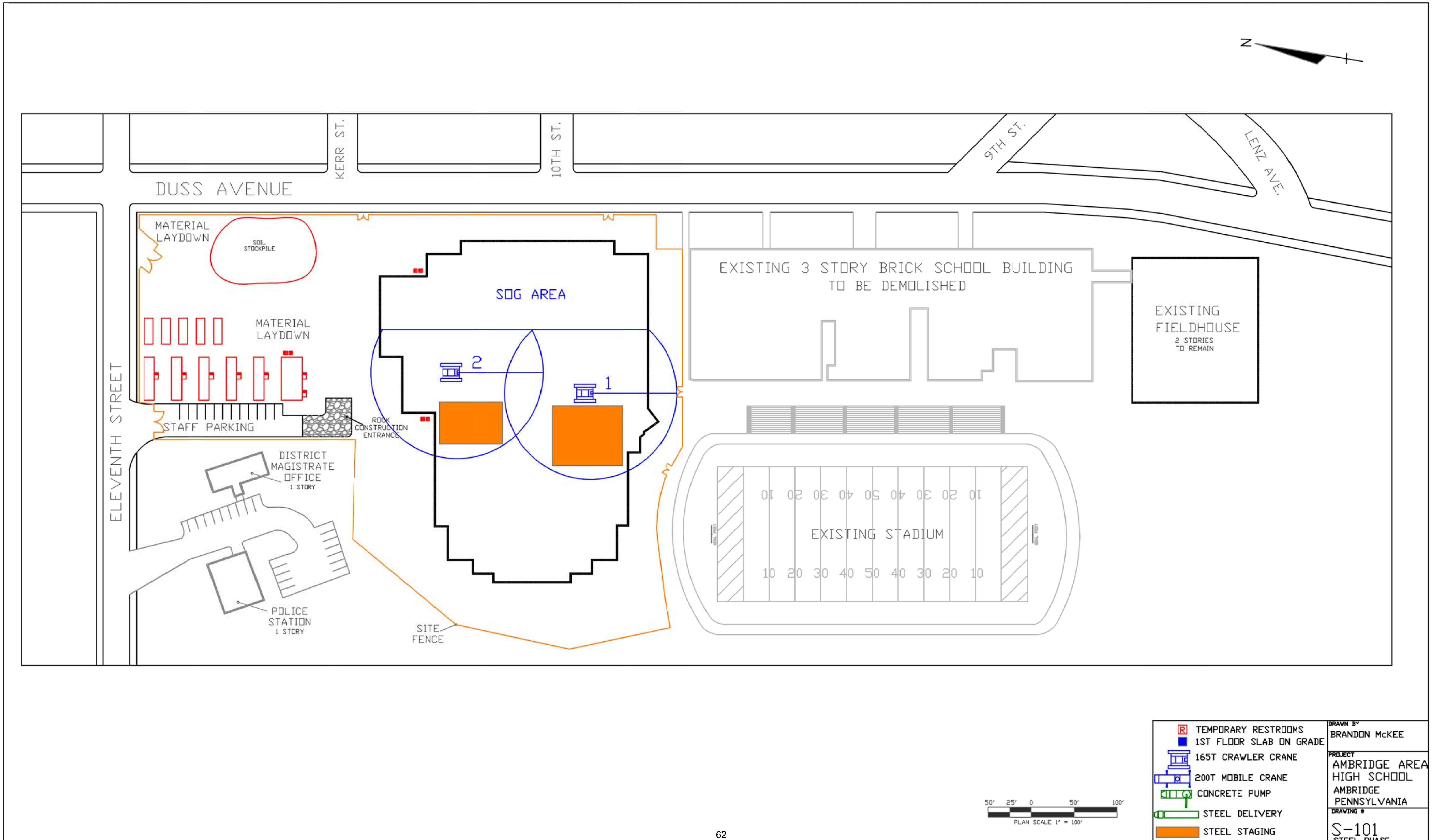
The first analysis was aimed at determining the barriers public school districts have to building green and achieving LEED certification on construction projects. Research was conducted surveying public school districts, architects, engineers and contractors collecting opinion of why schools choose not to go green. From the results, the primary reason is lack of knowledge and understanding of the LEED rating system and the benefits and advantages of green construction. A tool was developed serving as a lesson to be taught in high school settings to educate future adults of the benefits green construction has to offer to schools and buildings in general.

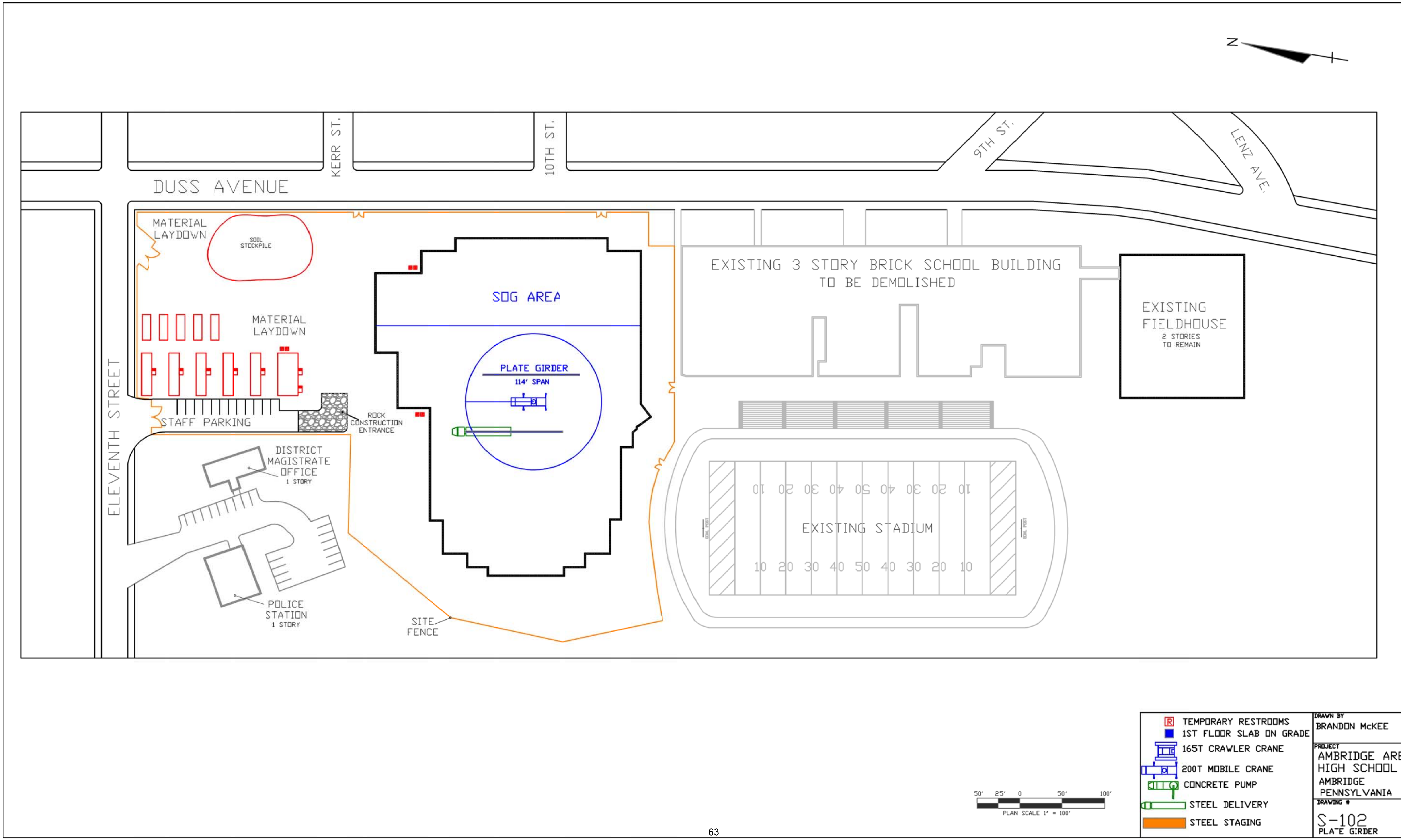
The second analysis looked to reduce the construction schedule and increase the thermal values of the exterior wall system by replacing the conventional masonry assembly with an architectural precast system from High Concrete. This system does place higher structural loads on the foundations but analysis proved they are sufficiently designed to carry this load. Mechanical impacts of incorporating this system are negligible as the thermal R-value of the two assemblies is close in magnitude.

The final analysis aimed to reduce the overall construction schedule by using an alternative steel and façade erection sequence allowing façade work to begin prior to the completion of steel erection. Using Navisworks 4-dimensional modeling, a sequence that allowed for completion of the exterior façade to occur one month earlier was created. While this change allowed the façade to complete earlier, other activities not covered in this analysis hindered its ability to reduce the overall construction schedule.

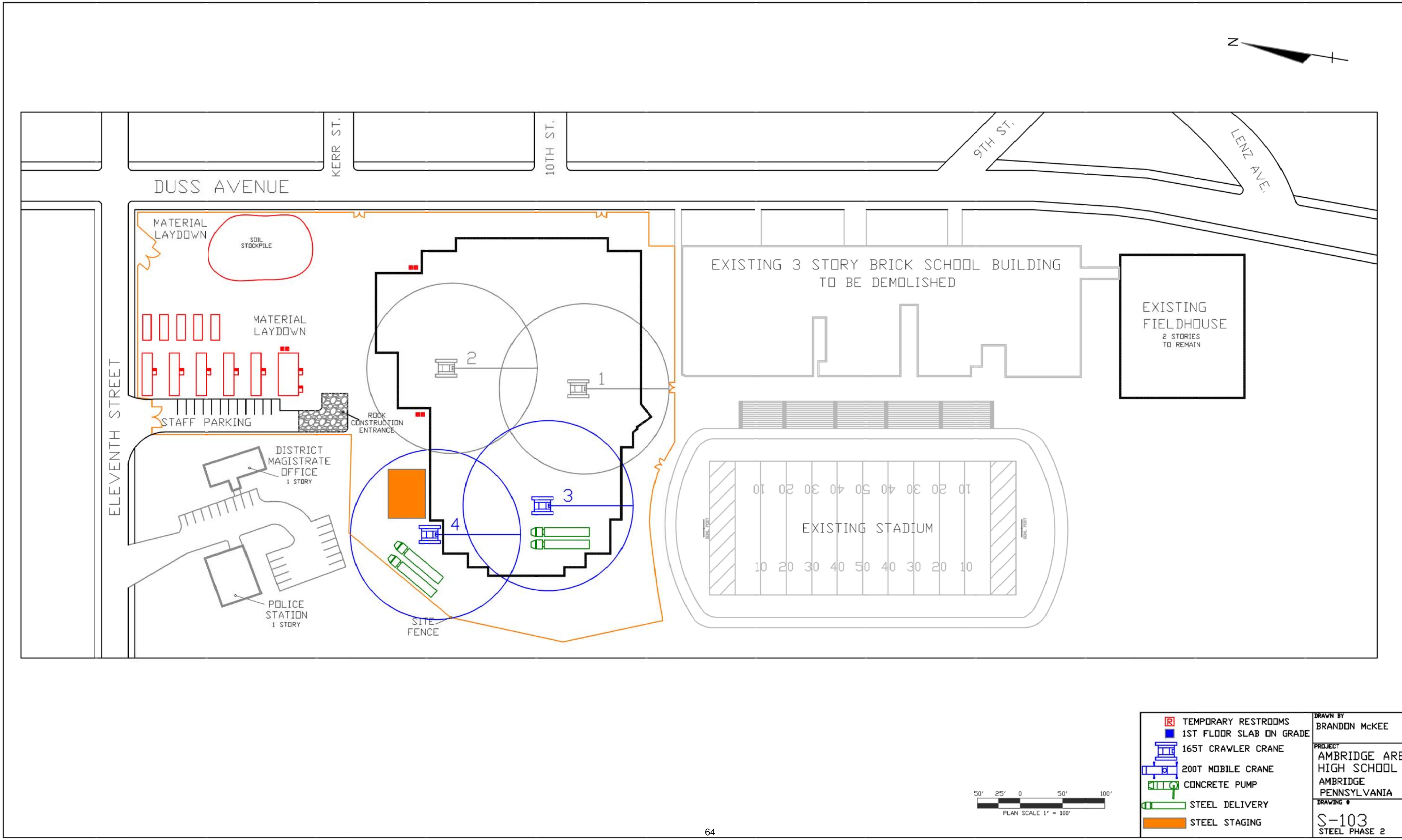
APPENDIX A

Project Site Plans

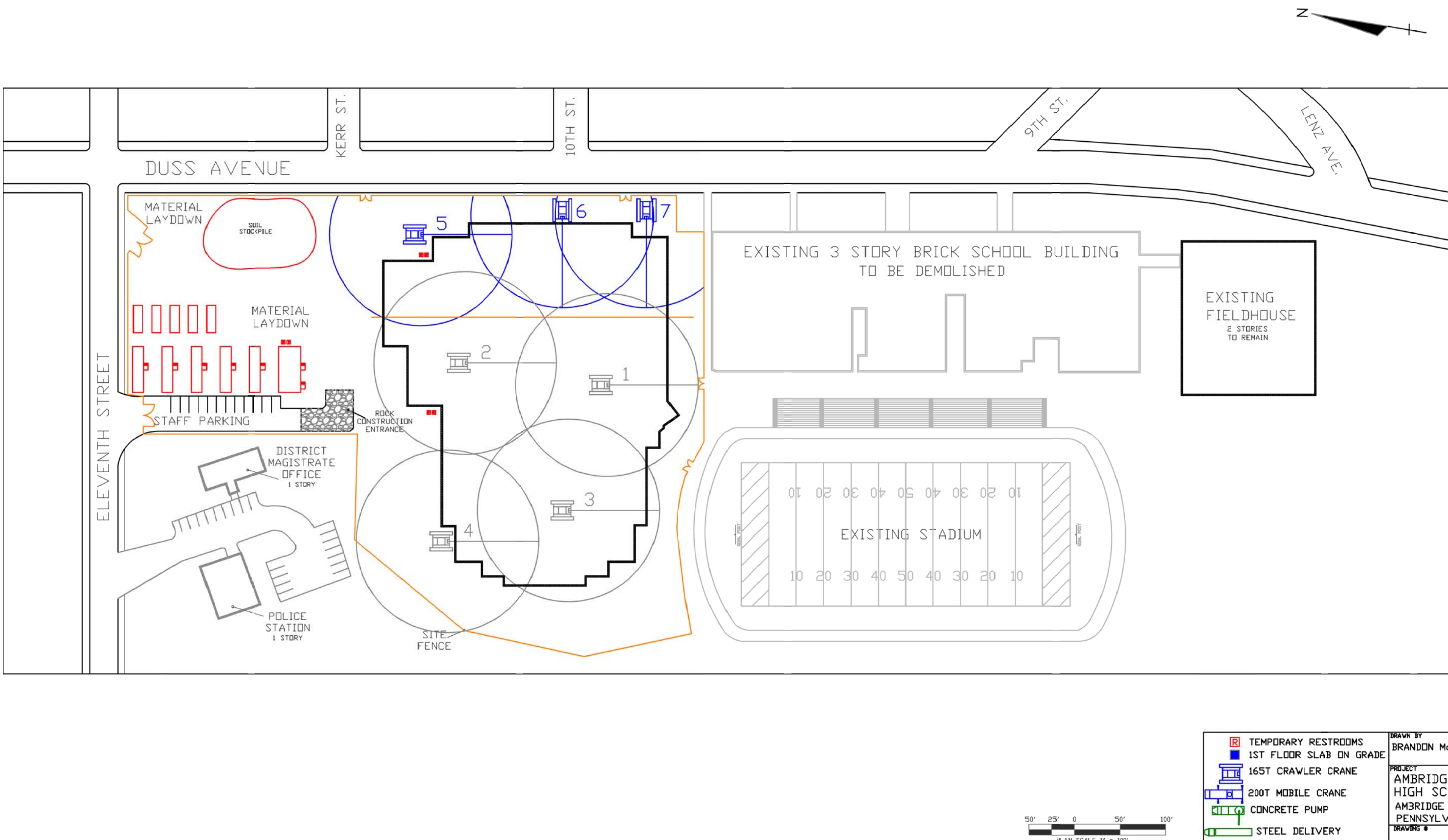

N
DUSS AVENUE
KERR ST.
10TH ST.
9TH ST.
LENZ AVE.
ELEVENTH STREET
MATERIAL LAYDOWN
SOIL STOCKPILE
MATERIAL LAYDOWN
STAFF PARKING
ROCK CONSTRUCTION ENTRANCE
SOG AREA
2
1
EXISTING 3 STORY BRICK SCHOOL BUILDING TO BE DEMOLISHED
EXISTING FIELDHOUSE
2 STORIES TO REMAIN
DISTRICT MAGISTRATE OFFICE
1 STORY
POLICE STATION
1 STORY
SITE FENCE
EXISTING STADIUM
10 20 30 40 50 40 30 20 10
TEMPORARY RESTROOMS
1ST FLOOR SLAB ON GRADE
165T CRAWLER CRANE
200T MOBILE CRANE
CONCRETE PUMP
STEEL DELIVERY
STEEL STAGING
50' 25' 0 50' 100'
PLAN SCALE 1" = 100'
DRAWN BY
BRANDON McKEE
PROJECT
AMBRIDGE AREA HIGH SCHOOL
AMBRIDGE PENNSYLVANIA
DRAWING #
S-101
STEEL PHASE



DUSS AVENUE
KERR ST.
10TH ST.
9TH ST.
LENZ AVE.
ELEVENTH STREET
MATERIAL LAYDOWN
SOIL STOCKPILE
MATERIAL LAYDOWN
STAFF PARKING
ROCK CONSTRUCTION ENTRANCE
DISTRICT MAGISTRATE OFFICE
1 STORY
POLICE STATION
1 STORY
SITE FENCE
SOG AREA
PLATE GIRDER
114' SPAN
EXISTING 3 STORY BRICK SCHOOL BUILDING TO BE DEMOLISHED
EXISTING FIELDHOUSE
2 STORIES TO REMAIN
EXISTING STADIUM
10 20 30 40 50 40 30 20 10
N
50' 25' 0 50' 100'
PLAN SCALE 1" = 100'
TEMPORARY RESTROOMS
1ST FLOOR SLAB ON GRADE
165T CRAWLER CRANE
200T MOBILE CRANE
CONCRETE PUMP
STEEL DELIVERY
STEEL STAGING
DRAWN BY
BRANDON McKEE
PROJECT
AMBRIDGE AREA HIGH SCHOOL
AMBRIDGE PENNSYLVANIA
DRAWING #
S-102
PLATE GIRDER



DUSS AVENUE
KERR ST.
10TH ST.
9TH ST.
LENZ AVE.
ELEVENTH STREET
MATERIAL LAYDOWN
SOIL STOCKPILE
MATERIAL LAYDOWN
STAFF PARKING
ROCK CONSTRUCTION ENTRANCE
DISTRICT MAGISTRATE OFFICE
1 STORY
POLICE STATION
1 STORY
SITE FENCE
EXISTING 3 STORY BRICK SCHOOL BUILDING
TO BE DEMOLISHED
EXISTING FIELDHOUSE
2 STORIES
TO REMAIN
EXISTING STADIUM
1
2
3
4
TEMPORARY RESTROOMS
1ST FLOOR SLAB ON GRADE
165T CRAWLER CRANE
200T MOBILE CRANE
CONCRETE PUMP
STEEL DELIVERY
STEEL STAGING
PLAN SCALE 1" = 100'
DRAWN BY
BRANDON McKEE
PROJECT
AMBRIDGE AREA HIGH SCHOOL
AMBRIDGE
PENNSYLVANIA
DRAWING #
S-103
STEEL PHASE 2

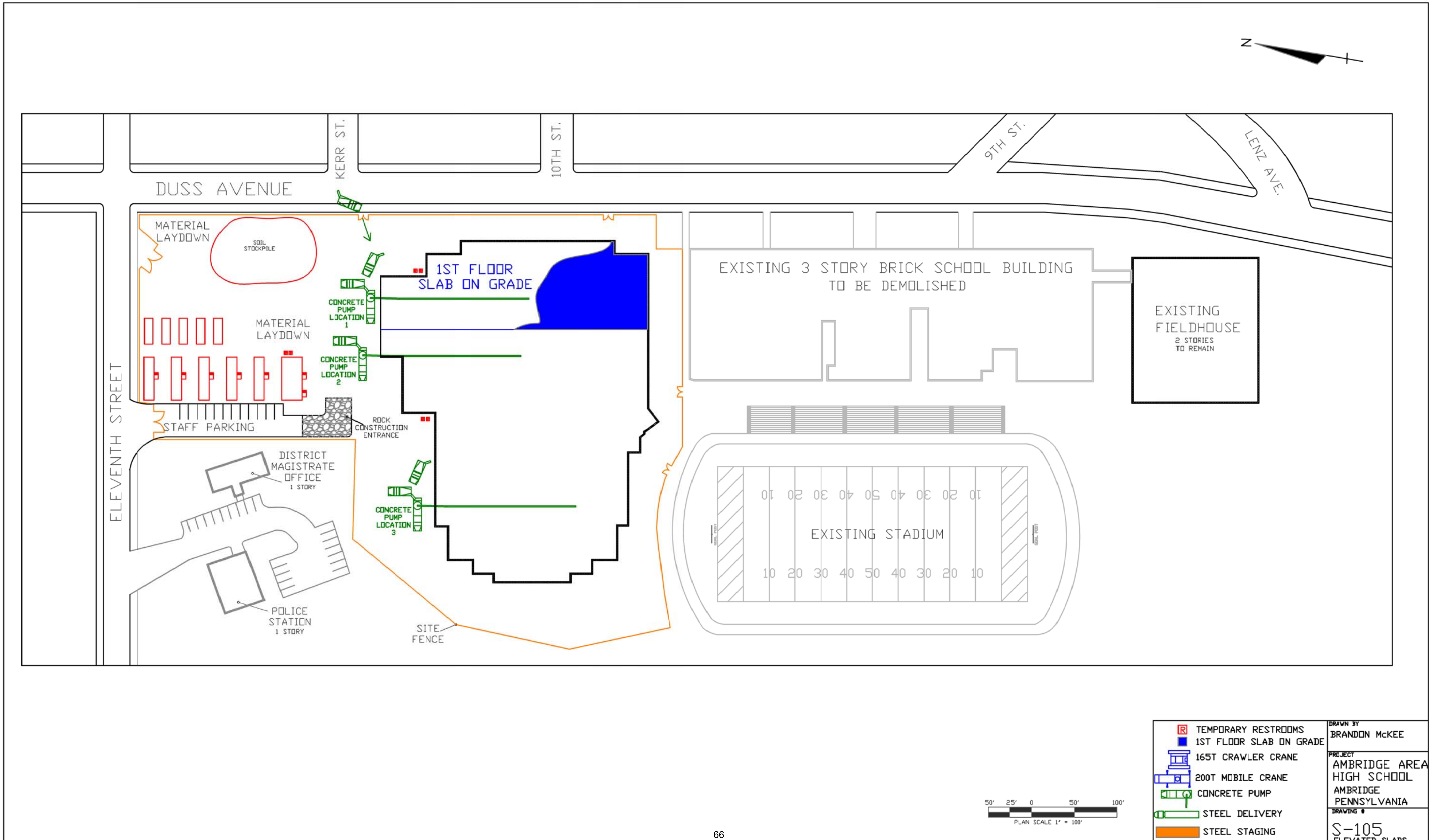


R TEMPORARY RESTROOMS
1ST FLOOR SLAB ON GRADE
165T CRAWLER CRANE
200T MOBILE CRANE
CONCRETE PUMP
STEEL DELIVERY
STEEL STAGING

DRAWN BY
BRANDON McKEE

PROJECT
AMBRIDGE AREA HIGH SCHOOL
AMBRIDGE
PENNSYLVANIA

DRAWING #
S-104
STEEL PHASE 3


DUSS AVENUE
KERR ST.
10TH ST.
9TH ST.
LENZ AVE.
ELEVENTH STREET
MATERIAL LAYDOWN
SOIL STOCKPILE
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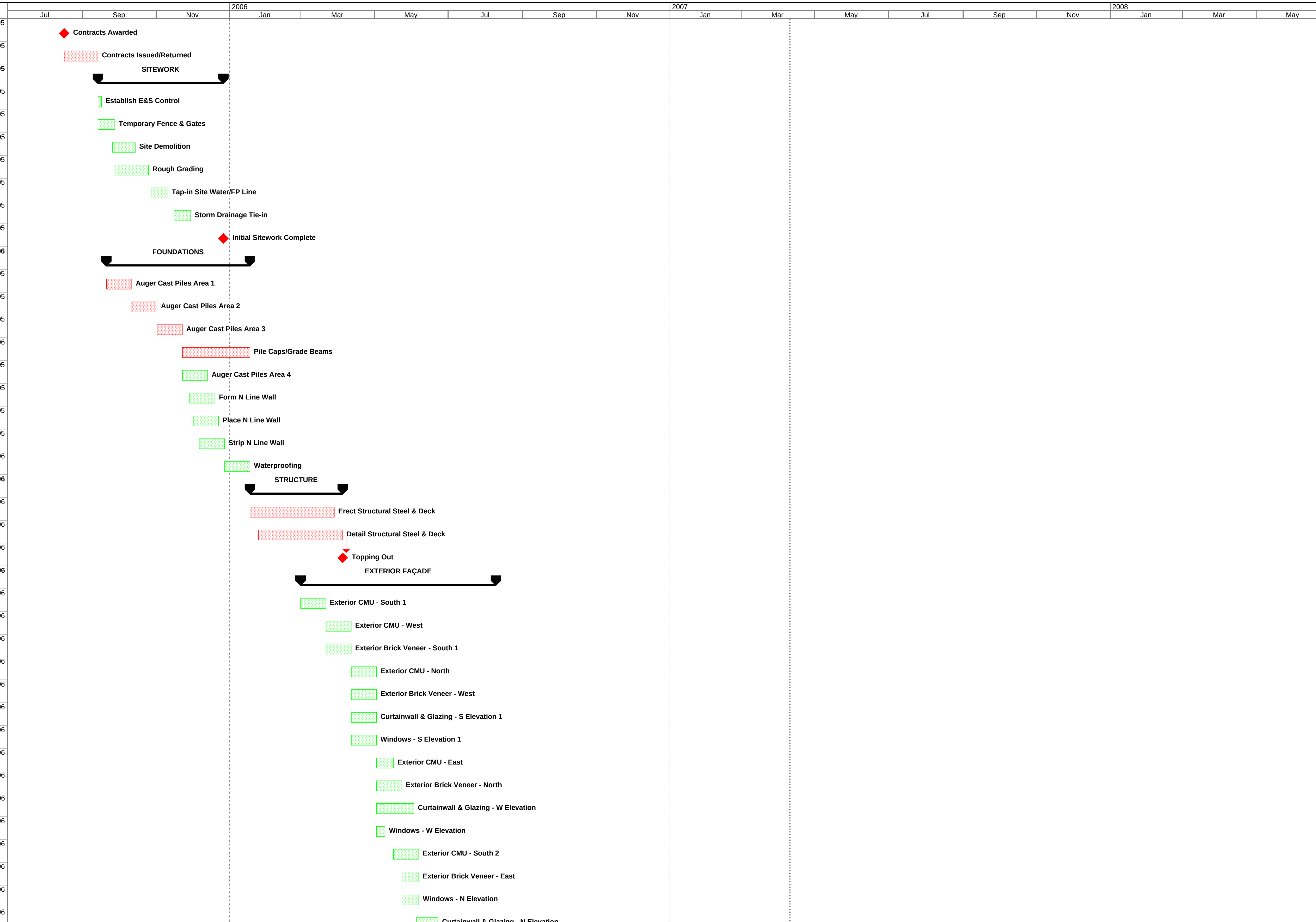
CONCRETE PUMP LOCATION 1
CONCRETE PUMP LOCATION 2
CONCRETE PUMP LOCATION 3
MATERIAL LAYDOWN
STAFF PARKING
ROCK CONSTRUCTION ENTRANCE
DISTRICT MAGISTRATE OFFICE
1 STORY
POLICE STATION
1 STORY
SITE FENCE
EXISTING 3 STORY BRICK SCHOOL BUILDING
TO BE DEMOLISHED
EXISTING FIELDHOUSE
2 STORIES
TO REMAIN
EXISTING STADIUM
10 20 30 40 50 40 30 20 10
N
50' 25' 0 50' 100'
PLAN SCALE 1" = 100'
TEMPORARY RESTROOMS
1ST FLOOR SLAB ON GRADE
165T CRAWLER CRANE
200T MOBILE CRANE
CONCRETE PUMP
STEEL DELIVERY
STEEL STAGING
DRAWN BY
BRANDON McKEE
PROJECT
AMBRIDGE AREA HIGH SCHOOL
AMBRIDGE
PENNSYLVANIA
DRAWING #
S-105
ELEVATED SLABS

APPENDIX B

Detailed Project Schedules

Ambridge Area High School
Summary Schedule

ID	Task Name	Duration	Start	Finish
1	Contracts Awarded	0 days	Wed 8/17/05	Wed 8/17/05
2	Contracts Issued/Returned	20 days	Wed 8/17/05	Tue 9/13/05
3	**SITEWORK**	**74 days**	**Wed 9/14/05**	**Tue 12/27/05**
4	Establish E&S Control	3 days	Wed 9/14/05	Fri 9/16/05
5	Temporary Fence & Gates	10 days	Wed 9/14/05	Tue 9/27/05
6	Site Demolition	15 days	Mon 9/26/05	Fri 10/14/05
7	Rough Grading	20 days	Wed 9/28/05	Tue 10/25/05
8	Tap-in Site Water/FP Line	10 days	Fri 10/28/05	Thu 11/10/05
9	Storm Drainage Tie-in	10 days	Wed 11/16/05	Tue 11/29/05
10	Initial Sitework Complete	0 days	Tue 12/27/05	Tue 12/27/05
11	**FOUNDATIONS**	**85 days**	**Wed 9/21/05**	**Tue 1/17/06**
12	Auger Cast Piles Area 1	15 days	Wed 9/21/05	Tue 10/11/05
13	Auger Cast Piles Area 2	15 days	Wed 10/12/05	Tue 11/1/05
14	Auger Cast Piles Area 3	15 days	Wed 11/2/05	Tue 11/22/05
15	Pile Caps/Grade Beams	40 days	Wed 11/23/05	Tue 1/17/06
16	Auger Cast Piles Area 4	15 days	Wed 11/23/05	Tue 12/13/05
17	Form N Line Wall	15 days	Tue 11/29/05	Mon 12/19/05
18	Place N Line Wall	15 days	Fri 12/2/05	Thu 12/22/05
19	Strip N Line Wall	15 days	Wed 12/7/05	Tue 12/27/05
20	Waterproofing	15 days	Wed 12/28/05	Tue 1/17/06
21	**STRUCTURE**	**55 days**	**Wed 1/18/06**	**Tue 4/4/06**
22	Erect Structural Steel & Deck	50 days	Wed 1/18/06	Tue 3/28/06
23	Detail Structural Steel & Deck	50 days	Wed 1/25/06	Tue 4/4/06
24	Topping Out	0 days	Tue 4/4/06	Tue 4/4/06
25	**EXTERIOR FAÇADE**	**117 days**	**Wed 3/1/06**	**Wed 8/9/06**
26	Exterior CMU - South 1	15 days	Wed 3/1/06	Tue 3/21/06
27	Exterior CMU - West	15 days	Wed 3/22/06	Tue 4/11/06
28	Exterior Brick Veneer - South 1	15 days	Wed 3/22/06	Tue 4/11/06
29	Exterior CMU - North	15 days	Wed 4/12/06	Tue 5/2/06
30	Exterior Brick Veneer - West	15 days	Wed 4/12/06	Tue 5/2/06
31	Curtainwall & Glazing - S Elevation 1	15 days	Wed 4/12/06	Tue 5/2/06
32	Windows - S Elevation 1	15 days	Wed 4/12/06	Tue 5/2/06
33	Exterior CMU - East	10 days	Wed 5/3/06	Tue 5/16/06
34	Exterior Brick Veneer - North	15 days	Wed 5/3/06	Tue 5/23/06
35	Curtainwall & Glazing - W Elevation	23 days	Wed 5/3/06	Fri 6/2/06
36	Windows - W Elevation	5 days	Wed 5/3/06	Tue 5/9/06
37	Exterior CMU - South 2	15 days	Wed 5/17/06	Tue 6/6/06
38	Exterior Brick Veneer - East	10 days	Wed 5/24/06	Tue 6/6/06
39	Windows - N Elevation	10 days	Wed 5/24/06	Tue 6/6/06
40	Curtainwall & Glazing - N Elevation	15 days	Mon 6/5/06	Thu 6/22/06



Project: Ambridge Area High School D
Date: Tue 4/10/07

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

Brandon C. McKee
Construction Management

ID	Task Name	Duration	Start	Finish
41	Exterior Brick Veneer - South 2	15 days	Wed 6/7/06	Mon 6/26/06
42	Windows - E Elevation	5 days	Wed 6/7/06	Tue 6/13/06
43	Windows - S Elevation	6 days	Wed 6/28/06	Wed 7/5/06
44	Curtainwall & Glazing - S Elevation 2	5 days	Wed 7/5/06	Tue 7/11/06
45	Temporary Entrances	5 days	Thu 7/6/06	Wed 7/12/06
46	Exterior Façade Complete	0 days	Wed 7/12/06	Wed 7/12/06
47	Erect Temporary Bridge	20 days	Thu 7/13/06	Wed 8/9/06
48	**Aluminum Entrances**	**22 days**	**Mon 4/30/07**	**Tue 5/29/07**
49	Aluminum Entrances - S Elevation 1	7 days	Mon 4/30/07	Tue 5/8/07
50	Aluminum Entrances - W Elevation	5 days	Wed 5/9/07	Tue 5/15/07
51	Aluminum Entrances - N Elevation	6 days	Wed 5/16/07	Wed 5/23/07
52	Aluminum Entrances - E Elevation	2 days	Thu 5/24/07	Fri 5/25/07
53	Aluminum Entrances - S Elevation 2	2 days	Mon 5/28/07	Tue 5/29/07
54	**ROOF**	**140 days**	**Wed 4/5/06**	**Tue 10/17/06**
55	EPDM Roofing System	40 days	Wed 4/5/06	Tue 5/30/06
56	EPDM Flashing	35 days	Wed 4/12/06	Tue 5/30/06
57	Roof Drains	20 days	Wed 4/19/06	Tue 5/16/06
58	Pyramid Framing / Roofing	20 days	Wed 5/17/06	Tue 6/13/06
59	Skylights	15 days	Wed 5/31/06	Mon 6/19/06
60	Set Mechanical Equipment	41 days	Wed 6/14/06	Tue 8/8/06
61	All Roof Work Done	0 days	Mon 10/16/06	Mon 10/16/06
62	Building Enclosure	0 days	Tue 10/17/06	Tue 10/17/06
63	**GROUND FLOOR**	**337 days?**	**Wed 3/15/06**	**Wed 6/27/07**
64	Underground Sanitary	40 days	Wed 3/15/06	Tue 5/9/06
65	Underground Storm	20 days	Wed 3/15/06	Tue 4/11/06
66	Conduits in Slab	40 days	Wed 3/15/06	Tue 5/9/06
67	Ground Floor Slab on Grade	30 days	Wed 4/19/06	Tue 5/30/06
68	Ground Floor Interior CMU	40 days	Wed 5/3/06	Mon 6/26/06
69	Ground Floor Cementitious Fireproofing	36 days	Thu 6/15/06	Wed 8/2/06
70	Sprinkler Mains & Branches	40 days?	Thu 7/13/06	Wed 9/6/06
71	Ductwork	40 days?	Thu 7/20/06	Wed 9/13/06
72	Emergency Generator	3 days	Wed 7/26/06	Fri 7/28/06
73	Ground Floor Rough Carpentry & Blocking	15 days	Thu 8/24/06	Wed 9/13/06
74	Ground Floor Stud Framing	40 days	Thu 8/24/06	Wed 10/18/06
75	Water Lines in Studs	40 days	Thu 9/21/06	Tue 11/14/06
76	Conduit & Boxes	40 days	Thu 9/21/06	Tue 11/14/06
77	Ground Floor Batt Insulation	30 days	Thu 10/19/06	Tue 11/28/06
78	Ground Floor Gypsum Board	50 days	Thu 11/9/06	Wed 1/17/07
79	Ground Floor Above Ceiling Work Complete	0 days	Fri 2/2/07	Fri 2/2/07
80	Ground Floor Acoustical Ceiling Grid	40 days	Mon 2/5/07	Fri 3/30/07

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

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ID	Task Name	Duration	Start	Finish
81	Ground Floor Corridor Ceramic Tile	25 days	Mon 3/19/07	Fri 4/20/07
82	Ground Floor Resilient Tile & Base	30 days	Mon 4/2/07	Fri 5/11/07
83	Ground Floor Finish Paint	20 days	Mon 4/23/07	Fri 5/18/07
84	Acoustical Ceiling Tile	10 days	Mon 5/14/07	Fri 5/25/07
85	Ground Floor Complete	0 days	Wed 6/27/07	Wed 6/27/07
86	**FIRST FLOOR**	**319 days**	**Wed 4/12/06**	**Fri 6/29/07**
87	Underground/ In Slab Sanitary	20 days	Wed 4/12/06	Tue 5/9/06
88	Underground/ In Slab Storm	10 days	Wed 4/12/06	Tue 4/25/06
89	Conduits in Slab	20 days	Wed 4/12/06	Tue 5/9/06
90	1st Floor Slab on Deck	10 days	Wed 5/31/06	Tue 6/13/06
91	1st Floor Slab on Grade	20 days	Wed 5/31/06	Mon 6/26/06
92	1st Floor Interior CMU	20 days	Wed 6/14/06	Mon 7/10/06
93	1st Floor Cementitious Fireproofing	40 days	Thu 7/13/06	Wed 9/6/06
94	Sprinkler Mains & Branches	40 days	Thu 8/10/06	Wed 10/4/06
95	Ductwork	40 days	Thu 8/17/06	Wed 10/11/06
96	1st Floor Stud Framing	50 days	Thu 9/21/06	Tue 11/28/06
97	Water Lines in Studs	40 days	Thu 10/19/06	Tue 12/12/06
98	Conduit & Boxes	40 days	Thu 10/19/06	Tue 12/12/06
99	1st Floor Batt Insulation	40 days	Thu 11/16/06	Wed 1/10/07
100	1st Floor Gypsum Board	60 days	Thu 11/23/06	Wed 2/14/07
101	Interior Brick - Lobby	10 days	Mon 1/22/07	Fri 2/2/07
102	Interior Brick - Auditorium	10 days	Mon 2/5/07	Fri 2/16/07
103	Quarry Tile - Kitchen	15 days	Mon 2/5/07	Fri 2/23/07
104	1st Floor Above Ceiling Work Complete	0 days	Fri 2/16/07	Fri 2/16/07
105	1st Floor Acoustical Ceiling Grid	40 days	Mon 3/5/07	Fri 4/27/07
106	Stage Equipment	25 days	Mon 3/26/07	Fri 4/27/07
107	Kitchen Equipment	15 days	Mon 4/2/07	Fri 4/20/07
108	Wood Floor System - Gym	25 days	Mon 4/9/07	Fri 5/11/07
109	1st Floor Corridor Ceramic Tile	25 days	Mon 4/16/07	Fri 5/18/07
110	1st Floor Resilient Tile & Base	30 days	Mon 4/30/07	Fri 6/8/07
111	Auditorium Seats	15 days	Mon 5/7/07	Fri 5/25/07
112	Finish Carpentry	15 days	Mon 5/21/07	Fri 6/8/07
113	Gymnasium Bleachers	15 days	Wed 5/23/07	Tue 6/12/07
114	1st Floor Finish Paint	20 days	Mon 5/21/07	Fri 6/15/07
115	1st Floor Complete	0 days	Fri 6/29/07	Fri 6/29/07
116	**SECOND FLOOR**	**332 days**	**Wed 5/10/06**	**Tue 8/14/07**
117	In Slab Sanitary	20 days	Wed 5/10/06	Tue 6/6/06
118	Conduits in Slab	20 days	Wed 6/28/06	Tue 7/25/06
119	2ND Floor Slab on Deck	30 days	Wed 6/14/06	Mon 7/24/06
120	2nd Floor Interior CMU	21 days	Wed 6/28/06	Wed 7/26/06

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

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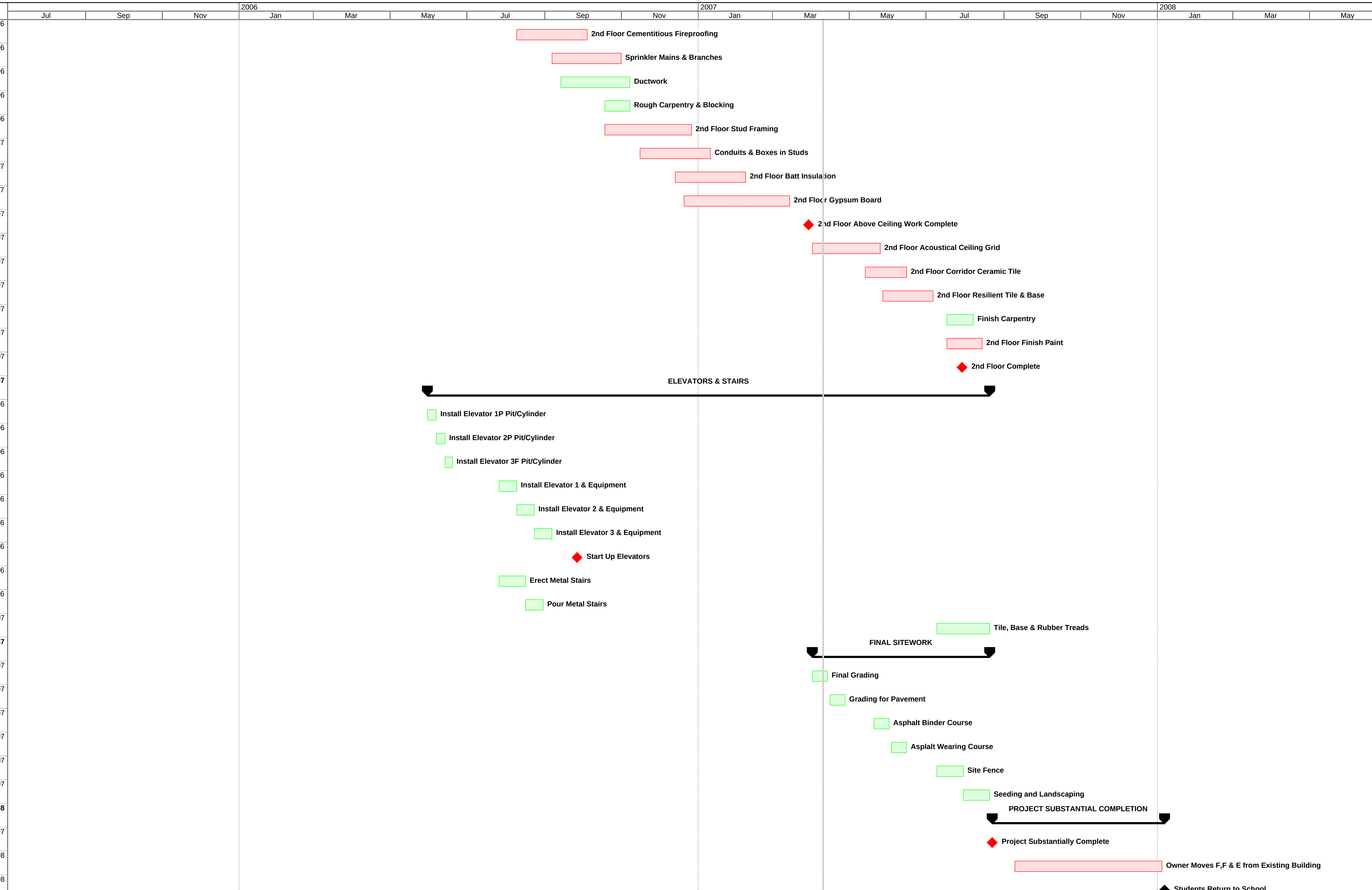
ID	Task Name	Duration	Start	Finish
121	2nd Floor Cementitious Fireproofing	40 days	Thu 8/10/06	Wed 10/4/06
122	Sprinkler Mains & Branches	40 days	Thu 9/7/06	Tue 10/31/06
123	Ductwork	40 days	Thu 9/14/06	Tue 11/7/06
124	Rough Carpentry & Blocking	15 days	Thu 10/19/06	Tue 11/7/06
125	2nd Floor Stud Framing	50 days	Thu 10/19/06	Tue 12/26/06
126	Conduits & Boxes in Studs	40 days	Thu 11/16/06	Wed 1/10/07
127	2nd Floor Batt Insulation	40 days	Thu 12/14/06	Wed 2/7/07
128	2nd Floor Gypsum Board	60 days	Thu 12/21/06	Wed 3/14/07
129	2nd Floor Above Ceiling Work Complete	0 days	Fri 3/30/07	Fri 3/30/07
130	2nd Floor Acoustical Ceiling Grid	40 days	Mon 4/2/07	Fri 5/25/07
131	2nd Floor Corridor Ceramic Tile	25 days	Mon 5/14/07	Fri 6/15/07
132	2nd Floor Resilient Tile & Base	30 days	Mon 5/28/07	Fri 7/6/07
133	Finish Carpentry	15 days	Wed 7/18/07	Tue 8/7/07
134	2nd Floor Finish Paint	20 days	Wed 7/18/07	Tue 8/14/07
135	2nd Floor Complete	0 days	Mon 7/30/07	Mon 7/30/07
136	**ELEVATORS & STAIRS**	**321 days**	**Wed 5/31/06**	**Mon 8/20/07**
137	Install Elevator 1P Pit/Cylinder	5 days	Wed 5/31/06	Tue 6/6/06
138	Install Elevator 2P Pit/Cylinder	5 days	Wed 6/7/06	Tue 6/13/06
139	Install Elevator 3F Pit/Cylinder	5 days	Wed 6/14/06	Mon 6/19/06
140	Install Elevator 1 & Equipment	10 days	Thu 7/27/06	Wed 8/9/06
141	Install Elevator 2 & Equipment	10 days	Thu 8/10/06	Wed 8/23/06
142	Install Elevator 3 & Equipment	10 days	Thu 8/24/06	Wed 9/6/06
143	Start Up Elevators	0 days	Wed 9/27/06	Wed 9/27/06
144	Erect Metal Stairs	15 days	Thu 7/27/06	Wed 8/16/06
145	Pour Metal Stairs	10 days	Thu 8/17/06	Wed 8/30/06
146	Tile, Base & Rubber Treads	30 days	Tue 7/10/07	Mon 8/20/07
147	**FINAL SITEWORK**	**101 days**	**Mon 4/2/07**	**Mon 8/20/07**
148	Final Grading	10 days	Mon 4/2/07	Fri 4/13/07
149	Grading for Pavement	10 days	Mon 4/16/07	Fri 4/27/07
150	Asphalt Binder Course	10 days	Mon 5/21/07	Fri 6/1/07
151	Asplalt Wearing Course	10 days	Mon 6/4/07	Fri 6/15/07
152	Site Fence	15 days	Tue 7/10/07	Mon 7/30/07
153	Seeding and Landscaping	15 days	Tue 7/31/07	Mon 8/20/07
154	**PROJECT SUBSTANTIAL COMPLETION**	**97 days?**	**Thu 8/23/07**	**Mon 1/7/08**
155	Project Substantially Complete	0 days	Thu 8/23/07	Thu 8/23/07
156	Owner Moves F,F & E from Existing Building	85 days?	Mon 9/10/07	Fri 1/4/08
157	Students Return to School	0 days	Mon 1/7/08	Mon 1/7/08



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

Brandon C. McKee
Construction Management

APPENDIX C

Green Schools Research Surveys

Green School Senior Thesis Questionaire

This form is designed to survey public school districts about the use of green building materials and methods in design and construction of schools. My research deals primarily with the absence of green design in public schools. Your submissions will remain confidential. Please answer all or as many of the questions as you feel comfortable with. Thank you for your time.

What is your name?

What is your Email Address

What school district do you represent?

What is the average size of a graduating class?

- Less than 49
- 50-99
- 100-149
- 150-199
- 200-249
- 250-299
- 300+

In what type of area is your district?

- Urban
- Suburban
- Rural

Has your district completed a construction or renovation project in the last five years or currently has one in progress?

- Yes
- No

Are you at all familiar with green building guidelines i.e LEED from the United States Green Building Council?

- Yes
- No

If yes, where did you gather this information from?

To what do you attribute the majority of operation and maintence costs of your school buildings?

What justification would be needed to incorporate technology into a new school building which carried a higher initial cost with potential cost savings over time.

Is there courses taught in your district on energy conservation, environmental impacts or other environmental type courses? If yes, please describe

* Indicates Response Required

Submit

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Green School Senior Thesis Questionaire

This form is designed to survey industry professionals about the use of green building materials and methods in design and construction. My research deals primarily with the absence of green design in public schools. Your submissions will remain confidential. Please answer all or as many of the questions as you feel comfortable with. Thank you for your time.

What is your name?

What is your Email Address?

Name of Firm

With what type of firm do you work?

- Architect
- Engineer
- General Contractor
- Specialty Contractor
- Consultant
- Other

With what type of project does your firm primarily deal?

- Office Buildings
- Higher Educational
- Primary/Secondary Education
- Healthcare
- Industrial
- Parking Structures
- Retail
- Hospitality
- Government
- Other

How many LEED accredited personnel does your firm employ?

- None
- 1-5
- 6-10
- 11-15
- 16+

How many total personnel does your firm employ?

- Less than 10
- 10-24
- 25-49
- 50-74
- 75-99
- 100-199
- 200-299

- 300-400
- 400+

Have you been involved with a LEED rated or green project?

- Yes
- No

If yes what involvement have did you play?

Has your firm suggested green alternatives to an owner or project team.

- Yes
- No

If yes, what were the suggestions and were they indeed incorporated? Why or why not?

What type of owner is most likey to insist on green design and construction?

- Developer
- Private Office
- Industrial
- Government
- Retail
- Healthcare
- Higher Education
- Primary/Secondary Education
- Other

What barriers do you believe owners/school districts have to using green design on new projects?

What comments do owners/school districts have toward savings over the life cycle if it means a higher first cost?

Do you feel owners (School Districts) have adequate information and understand the benefits of green building to make a decision to build green?

What would be the best way to demonstrate the benefits of LEED to project owners?

Please list any additional comments or suggestions on how to make this survey more effective

* Indicates Response Required

Submit

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