ASCE Charles Pankow Foundation Architectural Engineering Student Competition

Team Registration Number **05-2013**

Our team submitted designs in the following categories:

Building Integration Design
Structural Systems
Mechanical Systems
Lighting/Electrical Systems
Innovative Construction Management and Construction Methods

Executive Summary

The systems chosen for the Reading Elementary School were analyzed for constructability, initial cost and life cycle cost by the construction team. Below are some features and findings of the systems and areas which are explained in detail throughout this report.

Site Analysis..3

The building site was analyzed for asbestos, lead soil and sinkhole possibilities.

Building Enclosure..4

In order to have an efficient schedule, utilizing a precast exterior wall system was chosen to enclose the building quickly. This lets interior work start sooner and speeds up the overall project schedule while maximizing quality. Air leakage savings of approximately $2,500 per year cause a 10 year payback of additional initial costs.

Pool Area..5

By putting the pool and related facilities underneath the gym area, the project team was able to save $510,825 compared to creating a separate building, while integrating the space into the elementary school and creating a community garden for Reading to enjoy.

Classroom Spaces..6

Using a radiant floor and ceiling system with 100% outside air maximizes indoor air quality for students and faculty. This system draws a $22,000 in yearly savings to mitigate its higher initial cost; giving a payback period under 7 years. Quality control was essential to the planning construction of this system.

Energy Source..8

The project team has decided to utilize natural gas cogeneration of electricity to keep the elementary school's energy costs minimal. A major cost analysis was performed to ensure that using this system would save energy and be cost efficient over its life cycle. Using this system boasts $56,125 in energy savings and payback period under 3.5 years.

Construction Means and Methods..9

The logistics plan utilizes space efficiently and phasing led to choosing a single-direction flow of work throughout construction. Safety and sustainable construction practices and system had effect on the construction team as well.

Schedule and Cost..13

The Reading Elementary School project has been determined to take 14 months to complete and will cost $203.15 per square foot for a total cost of $21,344,312.

Community Involvement

The project team is committed to improving the Reading community through the implementation of educational programs for students and the public. A belief of giving back has spurred the team to commit themselves to 200 hours of service to Reading. During the project, members of the construction team plan to teach classes at the local schools, and sponsor trade school scholarship for high school students and community members. Service will be done on the first Friday and Saturday of every month.

Project Goals

The community of Reading, Pennsylvania is in a concerning state. In 2011, *The New York Times* ranked Reading as the poorest city in the United States on the basis of having the largest percentage of its population living in poverty. The Reading School district is in a comparable state. The school district is in “Corrective Action II” as defined by the No Child Left Behind Law, and has lately achieved mixed results in national and state standardized test scores.

The mission of the Charles Pankow Foundation is “to advance innovations in building design and construction, so as to provide the public with buildings of improved quality, efficiency, and value”. The 2013 ASCE Charles Pankow Foundation Student Competition forwards this mission by challenging students to use an integrated design method to create a high-performance elementary school located in the urban setting of Reading, Pennsylvania.

Working off of the challenges listed in the student competition guidelines and the mission of the Charles Pankow foundation, the design team formed goals for the project. These three goals form the team’s core values, and are crucial to the way members modeled the team’s design and decision-making processes.

Under each of the three team goals, there are construction specific items listed with symbols used throughout the report to highlight where each goal is met.

1. Build a better Reading community through construction and implementation of the school program
    - Deliver the building in a timely manner, so the community may enjoy it
    - Utilize systems which guarantee future savings for the school district in operations

2. Design the elementary school to high-performance standards
    - Use innovative construction methods to increase prefabrication of systems and reduce costs
    - Make technology the center of the planning process to leverage integration and increase quality

3. Utilize an integrated design approach to maximize quality, efficiency, and value of the final built product
    - Increase quality by planning for risky construction areas and addressing quality control for critical systems
    - Maximize project efficiency through phasing and schedule
    - Leave no stone unturned in researching new construction methods that meet project goals

Construction Goals

The construction team has taken into account the economic issues in Reading and is making sure that decisions made during the project are cost effective in relationship to value added. There is a need to give the city of Reading a high-quality school which can lead to a positive future for their youth, while considering the issues they face in the present. During design, it was mandated to avoid cost-cutting practices to make the school fit into an economically unstable area. Instead, the mentality has been investing in the future of Reading, and utilizing the value of innovative solutions to make the building reach its full potential. Maximizing efficiency during construction is an excellent way to deliver the project to the community it serves.

BIM Goals

- Focus on life cycle cost, while not forgetting initial cost
- Emphasize versatile spaces
- Have a well-documented project
- Involve all design disciplines in making decisions
- Create a building to unite the community and students within the school

Figure 1 shows a cut section of designed building for orientation purposes.

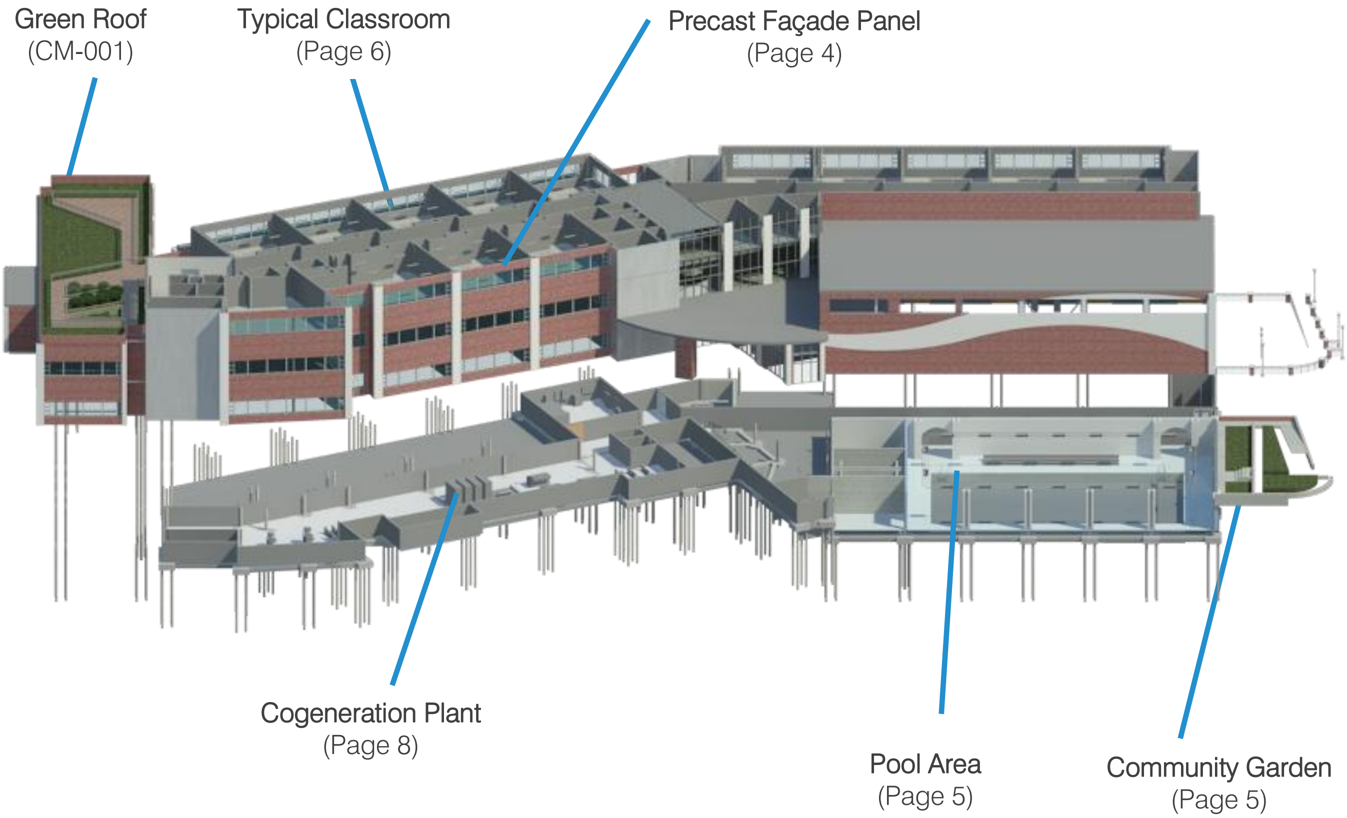


Figure 1: Exploded building sections

Building Areas

Site Analysis

The existing site plan posed several construction concerns which must be addressed to guarantee a successful project. With existing buildings on site being demolished, there is a risk of asbestos. An asbestos remediation plan was created in order to effectively handle any which may be in buildings on site. In the state of Pennsylvania, it is mandated that asbestos be removed from a construction site, and standards regulate the methods behind a remediation process. The generated process was broken into three different categories; planning, execution and acceptance.

Project documentation has shown that lead-contaminated soil exists on the project site. This could greatly impact site safety and the project schedule once excavation begins. Certain procedures will take place in order to safely remove hazardous soils from the construction site. The steps for removing contaminated soils include testing subsurface soil conditions, removal procedures and lead mitigation training for workers.

The geotechnical report for this project shows a high probability of sinkholes. A sinkhole can drastically delay a project and pose safety concerns, so it is imperative for construction personnel to be able to identify and plan for these risks. The project team will have guidelines to ensure worker and public safety on the project site and determine sinkhole prone areas. All members of the construction team must be aware of signs of sinkhole formation and the geotechnical engineer must be closely involved during excavation. Mitigation procedures have also been formulated. Detailed remediation protocols for asbestos, contaminated soils and sinkholes may be seen in the Supporting Documents pages 17-19 of this report. In them, there are detailed steps to be taken by the project team to assess all risks and ensure a safe project.

Building Enclosure

The façade system for the Reading Elementary School project was chosen to be an insulated sandwich precast façade panel. These panels are prefabricated with brick veneer set into the exterior concrete wythe, insulation and a paint-ready interior on the interior concrete wythe ("CarbonCast," 2012). Figure 2 shows an image of the designed panel used on this project. Materials and panel construction can be seen on drawing CM-002.

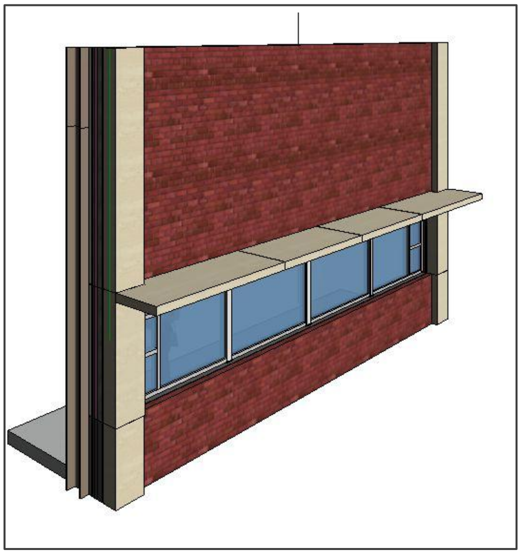


Figure 2: Top and bottom south façade precast façade panels with windows (typical)

Constructability

There are several advantages to using a precast exterior façade. Quality of the exterior wall system is a major reason why this façade was chosen. Precast panels are created in a fabrication facility off-site (PCI). As with any factory fabricated item, there are the benefits of people working on ground level in a comfortable and safe environment as opposed to laying brick in the cold of winter while standing on scaffolds. Since much of the exterior is repetitive, formwork for the panels can be reused multiple times, making the fabrication process repetitive and more efficient (MAPA, 2012).

Quality

By having continuous insulation throughout an entire panel, thermal bridging and leakage cannot occur, making an exterior wall system that performs better than any type of built up façade ("Building and Site Amenities"). The high performance of the system will incur energy savings of $2,000 to $3,000 per year by preventing air leakage.

Schedule Benefits

The schedule savings from using a precast façade system drove the decision to use an insulated sandwich wall panel (StructureMag, 2012). A precast façade will allow the building to be enclosed much faster than using a built up brick on metal stud wall system. The days saved by doing this are estimated to be 45. Reducing the schedule by 45 days will save the project $194,544 in general conditions alone (MAPA, 2012).

Cost

The cost of using this façade panel is higher than a built-up wall system, however because of its off-site fabrication; labor rates will be much lower than having a site fabricated exterior. Being a public project, prevailing wages will be utilized for labor on site, but materials fabricated off-site do not need to have the associated prevailing wage. Therefore, much of the additional cost for the precast façade system is offset. The total cost for this system is $1,631,750. Compared to a built up brick on stud wall system cost of $1,412,150, it is an added cost of $219,600. When taking into account the general conditions savings due to a shortened schedule, the precast façade system is an addition of $25,056. Because of air leakage energy savings, the payback period for using a precast exterior wall system is approximately 10 years. An estimate of this panel system is shown on page 20 of the Supporting Documents.

Pool Area

The project statement notes that the Reading School District would like to consider having and indoor pool incorporated into the elementary school project. This pool will include bleachers, locker rooms and any necessary equipment areas. A design decision was made to locate the pool in the basement beneath the gym in order to integrate it with other community and athletic related areas, as well as avoid the construction of an additional external structure. USA Swimming guidelines were consulted in the design of the space to ensure a proper competition atmosphere. Figure 3 shows the basic layout of the pool area. Figure 4 shows the Community Garden which is a series of setbacks on the west end of the school with windows to let natural light into the pool area. The community members will personalize this area by putting handprints on bricks and planting vegetation.

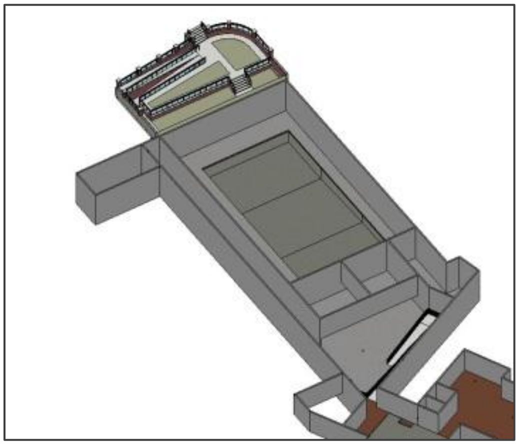


Figure 3: Pool area layout

Figure 4: Community Garden

Constructability

Locating the pool underground raises several constructability concerns which were addressed. Firstly, egress for the basement pool area needed to be taken into account to conform to IBC standards. To accommodate this, there are two stairwells which lead down to the basement within acceptable lengths from all spaces within the pool area. ADA standards were also addressed concerning the pool. Extending the elevator to the basement is one way for handicapped people to get to the basement level, but the pool area drops down an extra 6 feet from where the elevator lands. Non-handicapped people will use a short set of stairs to go down the extra 6 feet, and a ramp was constructed to allow handicapped people to be able to exit the elevator and proceed to the pool. There is also a set of ramps in the community garden for any handicapped people to be able to access that space.

With more excavation needed in this area, there is additional risk for sinkholes. There was a decision made to continue the usage of micro-piles as a foundation system, and combine that with grade beams supporting the pool. This gives structural stability and reduces the risk of opening sinkholes in this area. The cellular beams which will span the length of the pool and support the gym floor are going to be the most critical picks for the building, weighing at 3,600 pounds per beam and spanning 60 feet. They were taken into account during crane sizing, and the crane will be close to the pool area upon erection to make the process easier.

Cost

Creating the pool will obviously incur additional cost to the building project. However, the chosen design saves money compared to building a separate above-ground pool natatorium. Integrating the pool into the basement of the building warrants more initial excavation and retaining structures, but will save money compared to a new structure because there are no exterior wall needs, and much of the supporting structure exists even without the pool to support building loads. The pool cost was estimated to be $2,366,175 ($203.84 per square foot) when broken out of the final building estimate. The breakdown is shown on page 21 of Supporting Documents. This is significantly less than the $2,877,000 ($221.31 per square foot) cost for creating a new pool building. Having the pool beneath the gym not only integrates it into the building footprint, but will save the Reading School District approximately $510,825 dollars when compared to building an entirely new structure.

Classroom Spaces

The mechanical system being used in the classroom and office spaces of the elementary school project is a radiant system with 100% outside air. The system utilizes a radiant floor for heating and radiant ceiling panels for cooling of classrooms to provide a very comfortable and healthy environment. Other areas of the building, such as the gym and kitchen, will use a VAV system, which is more appropriate in those spaces. Constructing this type of system has many risks which were assessed and some advantages which can be taken into account. The maintenance cost associated with a system can be a deciding factor for building owners. Because a radiant system uses water for heating and cooling, the associated changing of filters and fans in a typical VAV system is greatly reduced. There are not as many pieces of equipment which need to go through constant maintenance or replacement, also keeping maintenance costs low. Figure 5 shows a 3D model of a radiant floor system which can be used to show various parties what composes the system for educational purposes.

Construction Benefits

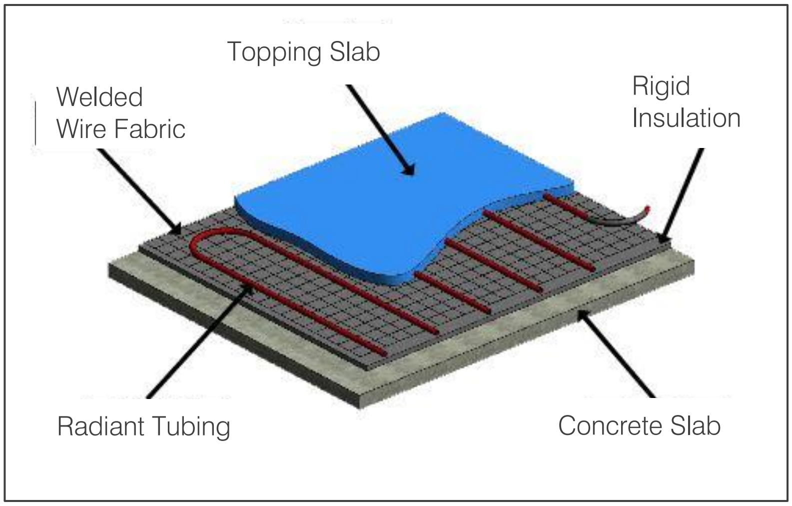


Figure 5: Radiant floor 3D model

Using a radiant system can benefit the construction process in some ways. The radiant ceiling panels are able to reduce significant amounts overhead work through prefabrication, which will save time and make construction safer and less expensive. Ceiling panels will be delivered to the site as prefabricated units, ready to be hung from the structure above and connected to branch piping. In addition to holding the radiant cooling tubes, the ceiling panels have lighting integrated to their design. A detail of a radiant ceiling panel can be seen on sheet CM-003 of the construction drawings. Coordination of systems within the classrooms will occur via an early bid package for subcontractors prior to fabrication. Figure 6 shows a modeled radiant ceiling panel with lighting suspended from it.

For the radiant floor system, mats can be made containing tubing tied to welded wire fabric. This allows mats of radiant tubing to be rolled out over a floor, saving time from laying out each radiant circuit. The concrete topping slab poured over the radiant floor will serve as the finished floor, saving money on finishing costs. The overall construction process for classroom mechanical systems is repetitive, since the layout is the same for each classroom. Repetitive processes lead to increased production and safety.

Risk Mitigation

Being an uncommon system to build, there are associated risks in the construction of a radiant mechanical system that were addressed. Since there will be water tubes imbedded in the finished floor, it is crucial that the coordination process happens early. Core drilling will not be able to be done in most of the classroom due to the risk of puncturing tubes. Therefore, all clashes must be remedied well in advance of construction and submittals need to be approved in a timely manner. To accommodate potential core drilling, there is a designated core drilling area located in the interior wall chases.

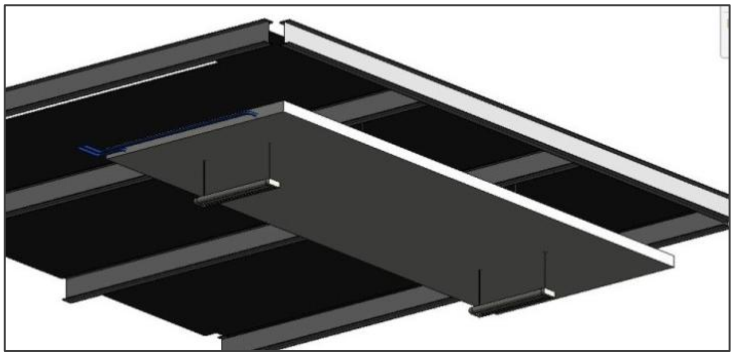


Figure 6: Radiant ceiling panel 3D model

Leakage is a major concern for the radiant floor. If a topping slab is poured and a leak is found, the project budget and schedule will suffer. To assess this, each room will have radiant floor circuits pressure tested and approved prior to topping slabs being poured. This will ensure that leaks do not occur in any radiant space.

Since quality control of classroom construction is crucial with radiant flooring and ceiling panels, modeling can be used to show owners and contractors how the construction of this system looks and how classrooms will be built out. To assist with this, a 4D model of a typical classroom was created to show how work will flow throughout the classroom spaces. Images from that model are on drawing CM-005. Figure 7 is an image of the model used in the construction sequence.

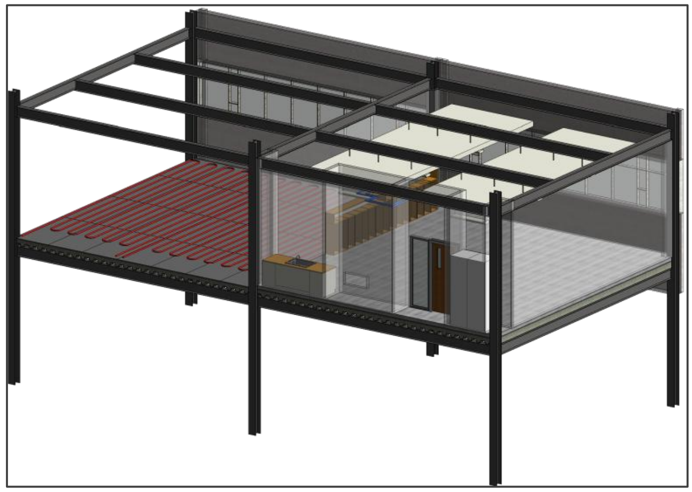


Figure 7: Classroom model used in 4D

With an uncommon system comes a lack of familiarity in construction. There is a possibility that a local labor force to perform this kind of work does not exist, so subcontractors from further away may need to be brought in to perform the radiant piping. The team plans on sourcing local labor first and suggesting joint ventures with distant firms for inexperienced, but qualified subcontractors. The maintenance staff for the school is also likely to be unfamiliar with this type of system. To familiarize them, it is recommended to have facility managers brought into the project early to earn an understanding of how the system works and how to resolve any issues.

Design Review

To take the Typical Classroom model a step further, an interactive virtual reality 3D walkthrough was created using the Unity program. Several teachers were asked to review the layout and design of classroom spaces. This helped to further design features such as outlets, interactive whiteboard location, thermostat placement and light switches. Much validation of the design also occurred by doing this, as can be seen in Figure 8. The team Integration narrative explains this in further detail. From a construction standpoint, a design review allows more input of end users and maintenance personnel in functionality of building components. This can speed up the decision making process, so construction can begin as soon as possible. The feedback from the design review yielded preferences on interactive whiteboard location and desired quantities of computers in each room.

Cost

Using a radiant system has added costs compared to a VAV baseline. The system is more efficient than a more standard approach and therefore saves more energy over other mechanical systems. These energy savings can provide a payback period for using the radiant system. In the classroom spaces alone, the additional price of using the proposed system is $149,766, $2.18 per square foot, more than a rooftop multi-zone VAV system. However, because of significant energy savings of $22,000 per year, the additional cost will be equated in a period of 6.81 years. Since this is a school which will have a life well over 50 years, the system's long payback period is acceptable. A cost breakdown can be seeing on page 23 of the Supporting Documents.

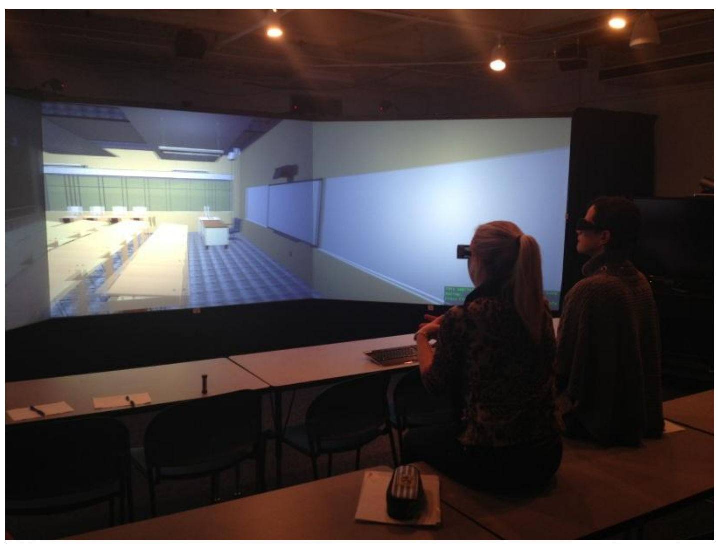


Figure 8: Teachers reviewing the proposed classroom design for validation.

Energy Source

To add an innovative element to the building and provide additional energy saving benefits, the project team has decided to utilize energy cogeneration. This will be done via a natural gas fueled microturbine. Since this is not an often used piece of equipment, the constructability, cost and maintenance concerns associated with the microturbine were analyzed to determine feasibility.

Figure 9: Size of a microturbine can be realized through this image. Courtesy of http://www.wbdg.org/resources/microturbines.php

Constructability

The first item to analyze was constructability concerns. Much research was done to figure out the construction risks of installing a microturbine. The equipment package is contained in a single unit, which is about the size of a standard home refrigerator ("Choosing Cogen," 2012). Three 100kW microturbines will be used in this project. To better define the size, Figure 9 shows a technician standing by several microturbines.

The units may be located indoors, so it has been decided to bring them through the mechanical equipment grate leading to the mechanical room in the basement. The units will need to have natural gas piping connected to them and raceways for electricity to run from a unit to the switchgear. Microturbines are known for producing a high-frequency noise averaging around 65 dB and getting louder with time, making sound retardation of their area a necessity ("Microturbines," 2012).

Cost

The building schedule will not be affected by the addition of microturbines as the lead time for them is 12 weeks from ordering date. Microturbines were integrated into the rest of the building design since many disciplines are involved in their installation. The installed cost of the microturbines will be $467,250 with a yearly maintenance cost of $10,500 ("Choosing Cogen," 2012). The Pennsylvania Alternative and Clean Energy State Grant can award the school up to $2,000,000 because of the usage of cogeneration. The project team decided to conservatively choose a grant of $250,000, while nearly $500,000 in grants have been awarded to public buildings utilizing similar wattage microturbine systems. Energy savings per year from electricity and the usage of waste heat for water heating generated by the microturbine were tabulated by mechanical and electrical engineering disciplines of the project team and projected to be $56,125.

Making the use of microturbines even more attractive is the elimination of a generator in the building. With an on-site fuel source, the microturbine can be used in lieu of a generator in emergency situations. Table 1 shows how all associated costs and savings for the microturbine are combined to give a life cycle cost of $187,250 and payback period of 3.4 years for the system. Without the benefit of an energy grant, the payback period is 7.8 years.

Microturbine Cost (http://www.wbdg.org/resources/microturbines.php)		
Category	Avg. $/kW	Cost
Initial Cost (300 kW)	$900	$270,000
Heat Recovery	$213	$63,750
Total Equip. Cost		$333,750
Installation (% of others)	40%	$133,500
Microturbine Installed Cost		$467,250
Avoided Generator Cost		-$200,000
Energy Grant		-$250,000
Total Initial Cost		**$17,250**
Yearly Maintenance (kWh)	$0.0105	$10,500
*estimate 1,000,000 kWh/year		
Avoided Generator Cost ($/yr)		-$2,000
For 20 Year Life		$170,000
System Life Cycle Cost		$187,250
Yearly Energy Savings		$56,125
Payback Period (years)		**3.34**
Replacement Cost		$378,000

Table 1: Microturbine life cycle cost breakdown.

Maintenance

It is highly unlikely that facility managers are familiar with microturbines, so educating them and getting operations staff involved in the design and construction process is crucial to educate all staff on the workings of the equipment. Manufacturers will monitor the equipment status, keeping operation and troubleshooting by staff minimal. Regular maintenance by a technician is needed every 5,000 to 8,000 hours of operation (about once per year), and the product has a total service life of 20 years. After replacement of the units, there is a payback period of 6.73 years. The facility manager will need to be aware of this when scheduling maintenance of equipment in the building (“Choosing Cogen,” 2012). Since the building will be connected to the electrical grid, there is no risk of losing power when microturbines are shut off for maintenance.

Construction Means and Methods

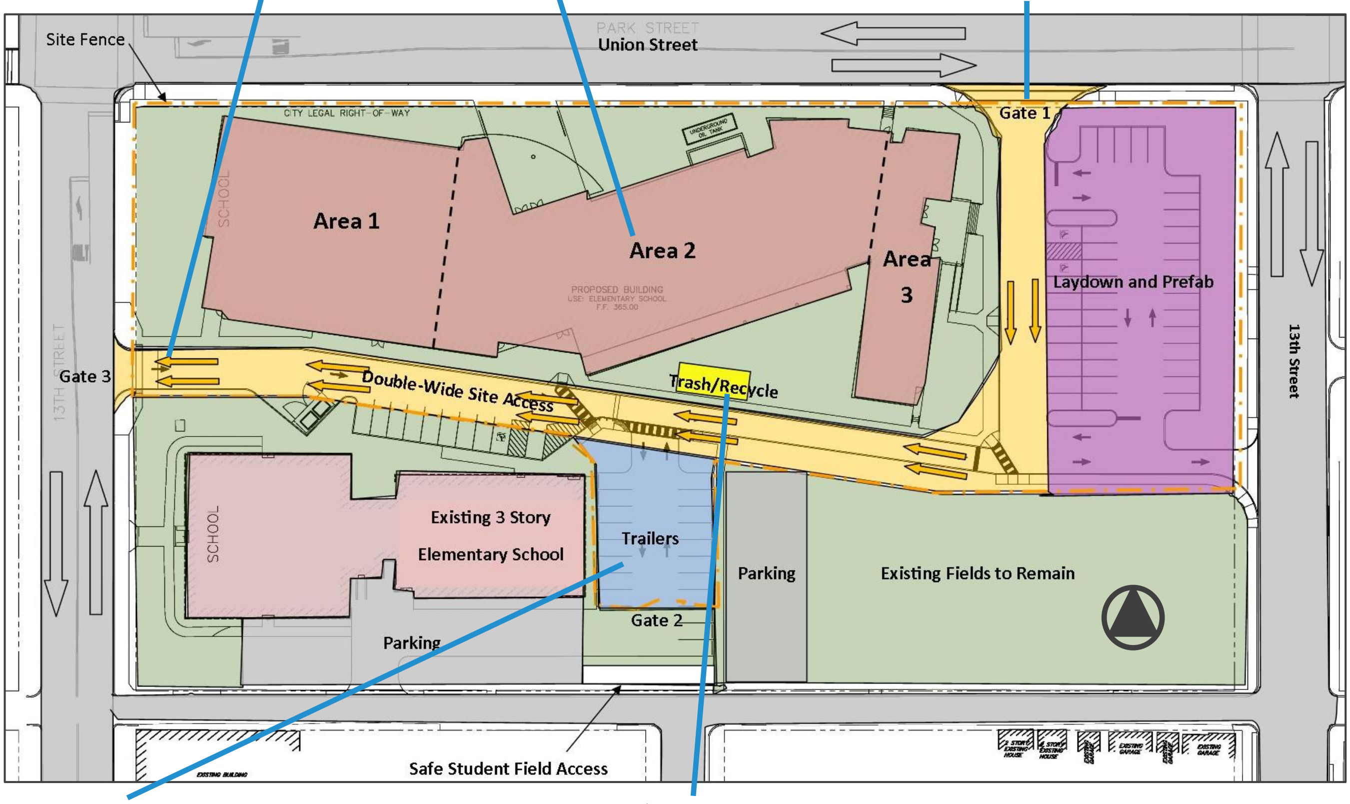
Site Logistics

After identifying hazards on the site, the construction team can accurately plan how the site will be utilized as well as how work will flow once construction begins. The project safety plan, highlighting all safety concerns during construction, can be seen on drawing CM-006. Figure 10 shows a general site logistics plan during construction.

Site Access:
- Along finished service road
- One-way and double-wide for vehicles to pass parked ones
- Access to full Laydown/Prefab area

Areas 1, 2 and 3:
- Used for phasing/sequencing
- Areas chosen based on varying excavation depths and structural breaks

Gates:
- Gates 1 and 3 for trucks
- Gate 2 for worker access
- Multiple emergency egress routes



Trailers:
- Centrally located for supervision

Trash/Recycling:
- Centrally located for ease of access
- Dumpsters may remain here throughout project duration
- Near access road for simple waste pickup

Figure 10: Building site logistics plan

Several items were considered in developing a general site logistics plan such as site access, safety, the existing elementary school and field, possible laydown areas and logical flow direction. After considering all factors, this site plan allows the efficient use of the work areas. The methodology behind creating the site plan was to only utilize areas which will need construction during the project. An example of this is the laydown and prefabrication area which is located where the elementary parking lot will upon project completion. However, the fields will be as unchanged throughout construction and remain untouched. Leaving the field be during the construction process will allow the community and existing elementary school to be able to use the field for sports and recess activities. The existing elementary school will remain open during construction for school and community activities, too.

3D Logistics Models

In order to get a better visual of the project logistics, a 3D Google SketchUp model of the logistics plan was created. This was further altered into phased logistics plans to show where equipment will be located and what each project phase will look like during construction. To elevate the understanding of site logistics, an augmented reality model was created. Utilizing an augmented reality model will allow an evaluation of the logistics plan to take place prior to construction, preventing issues from occurring in the field. This can also show subcontractors where their equipment will be on site and where all trades will be at certain points of the project.

Phasing and Sequencing

The new elementary school will be phased along with the demolition of the three existing structures on the project site. The existing elementary school is to remain for the project duration. There are three major logistical phases which are demolition, excavation/foundations and superstructure. The project team wanted to reduce the overlap of trades in each area to keep work efficient. Figure 11 shows the initial phase, which is the demolition of the three existing buildings.

Figure 11: Demolition logistics plan.

In Figure 11, it is able to be seen how demolition will be sequenced. The most western existing building will be demolished first, followed by the start of that area's excavation. Since this area will have the most excavation (20 feet) in the entire building, it is appropriate to do this region first. Next, the most eastern building will be demolished in order to make the site access road and the necessary space for the laydown and prefab area. The center existing building will be demolished last. Trucks will have a turnaround point during demolition until the access road can be cleared. Following demolition of all structures, excavation will continue and foundations will begin to be set. This is shown in Figure 12 on the following page.

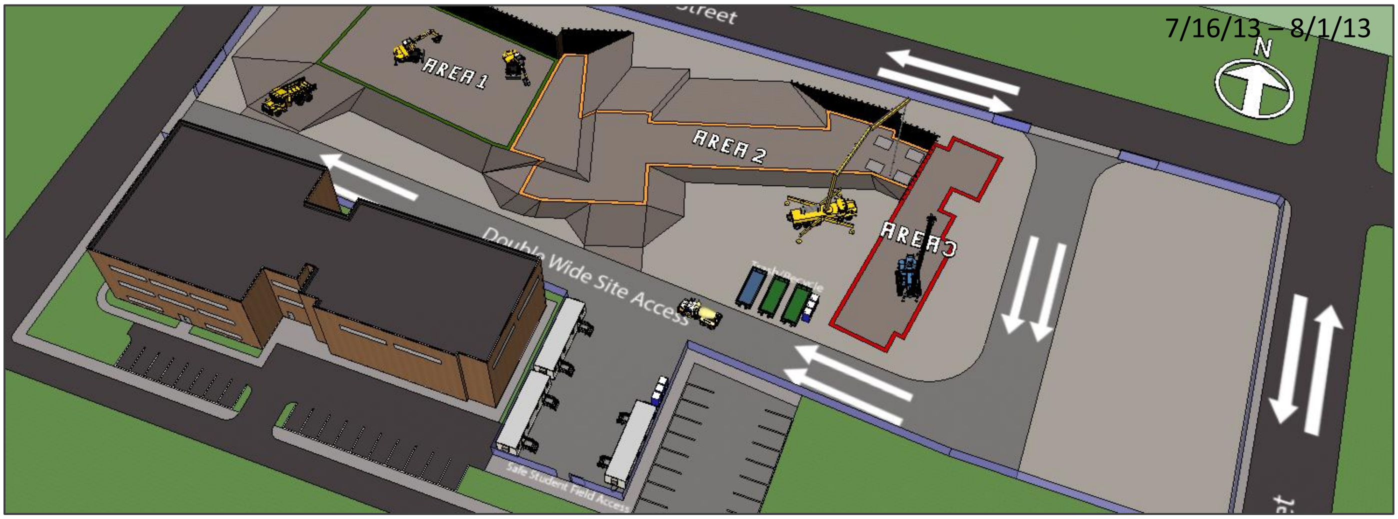


Figure 12: Excavation and foundations site plan.

During this project phase, excavation will continue to occur in the deepest basement of Area 1 and will have just been completed in Area 2, allowing foundation work to begin. Soldier beams and lagging will be used as temporary shoring where needed. The foundation system consists of driven micro-piles, warranting pile driving equipment on site along with a concrete pump truck to pour pile caps. Area 3 does not contain a basement, so it will have foundation work starting after Area 2 finishes, and Area 1 will have foundation work commence last.

When the building structure begins erection, the work flow will be from east to west since Areas 2 and 3 will have completed foundations while those in Area 1 are finishing. The superstructure logistics plan was created showing the busiest time during the project and can be seen in Figure 13.

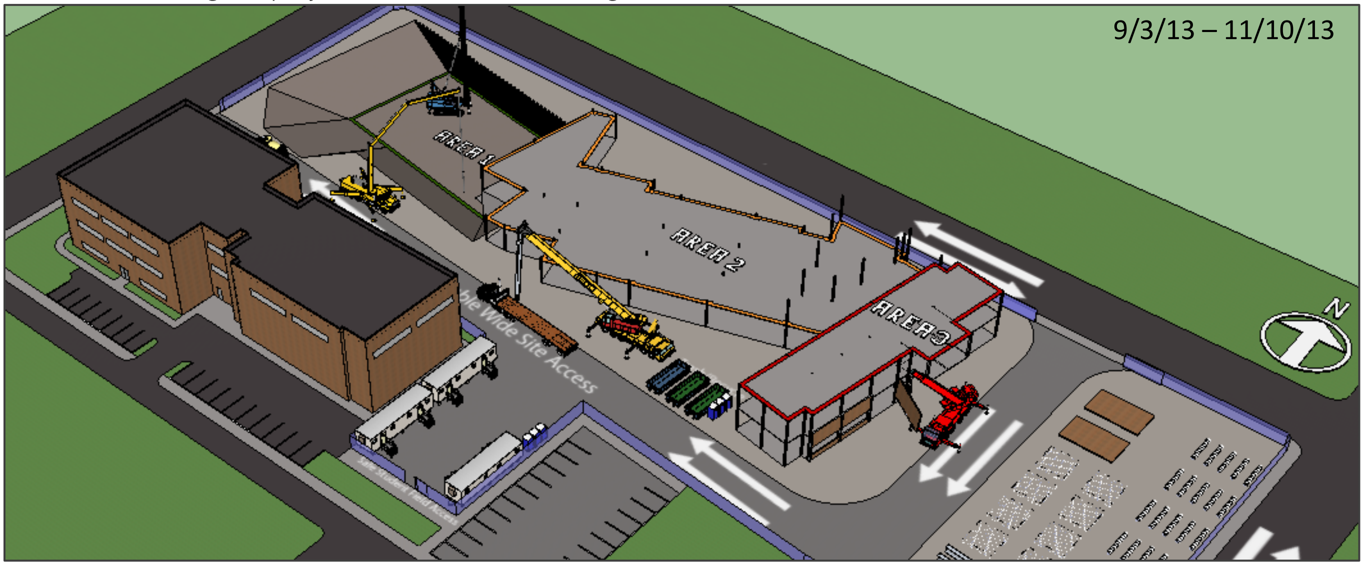


Figure 13: Superstructure site plan.

In this phase of the project, there are three activities occurring at the same time. In Area 1, foundation work is almost complete, with final concrete pours being done. Areas 2 and 3 will have had their first floor structural steel work completed simultaneously, since the first floor in those areas must be erected together for structural stability. Area 1 is not structurally dependent on any other part of the building, allowing it to be built separately. After the first floor structure is assembled, Area 3 will top-out with steel on the second floor, allowing it to receive precast façade panels by use of a second crane. This will free the main crane to erect the remaining two floors of steel in Area 2 before moving to the structure of Area 1. Having the crane set in this location allows the structural framing to be erected throughout Areas 2 and 3 with very little crane movement. The crane swing radius of 165 feet is sufficient as steel erection begins to erect the second and third floors of Area 2.

The progression of structural and façade work is also east to west. Having work flowing in a single direction allows multiple activities to occur simultaneously to keep the process efficient. This also keeps the construction site organized and safe.

Equipment on site during this project phase includes the concrete pump which will have moved several times during foundation pouring, as well as the two cranes. Referencing Manitowoc crane specifications and critical pick loads, the crane sizes needed for the project were determined. The steel erection crane will be a 130 ton all-terrain crane with a 197 foot boom length. This crane will be able to carry the maximum pick load of 3,600 pounds at 165 feet away from the crane base and 60 feet above ground. The all-terrain style of crane allows maneuverability on site and a telescoping boom for versatility. The secondary crane, used for façade panel installation, will also be an all-terrain crane. It will be smaller in size, due to the lower distances that it will reach. A 60 ton all-terrain crane with a maximum 140 foot boom length will handle the loads during precast panel erection ("GMK3055," 2012).

A 4D model has been created to give a better visual of work flow throughout the construction process. It can be an effective tool to show owners and contractors how the construction of the building will progress along with schedule data and images from this model may be seen on drawing CM-005.

Sustainability

During the construction process, several sustainability practices will be used to help gain LEED points for the building. The Lead Soil Remediation Plan mentioned earlier helps to earn credits in the Brownfield Redevelopment portion of Sustainable Sites in LEED. The other points obtained by the construction team come from the Materials and Resources category. Demolishing buildings on site has given the team an opportunity to recycle much of that material. The project team also plans to recycle of waste during the construction process. Using regional materials is not only a sustainable practice, but cheaper in many applications and can stimulate the local economy. Lastly, the project team is obtaining a credit in the Certified Wood section. More LEED information and credit breakdowns can be seen in the Supporting Documents section in the Integration Narrative.

System Coordination

It is imperative that all building systems are coordinated before construction begins so field clashes are avoided. To do this, each discipline worked together throughout design and discussed dimensions, main system run locations and equipment placement. Next, each discipline put their designed systems into a Revit central model file. Navisworks' Clash Detective tool was finally used to find where systems interfered with each other.

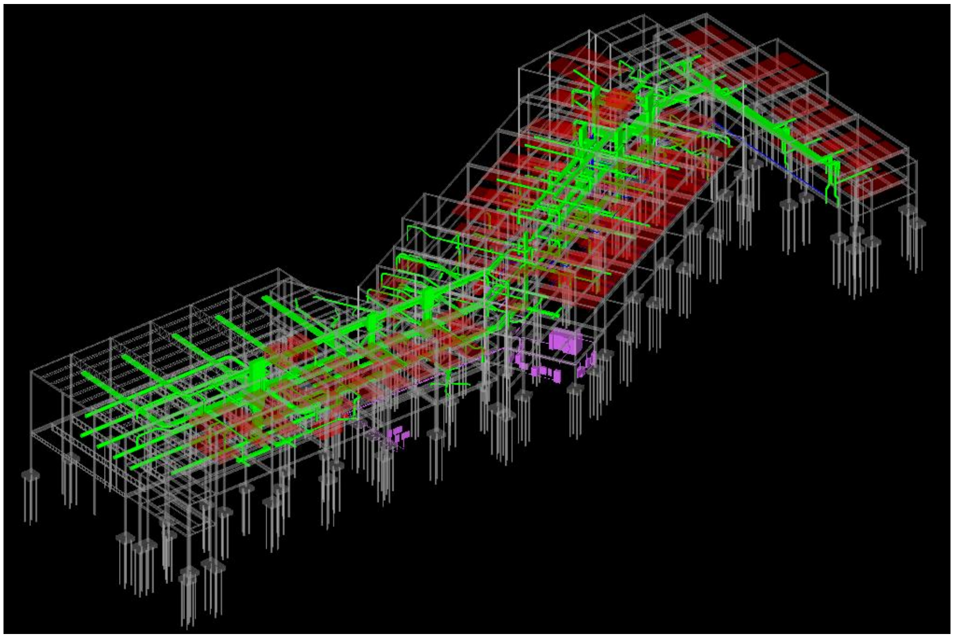


Figure 14: Image of 3D model used for clash detection.

Coordination meetings were led by construction team members to ensure a smooth building process. Due to the mechanical system chosen, amounts of ductwork were reduced significantly. This assisted the coordination process and the team yielded zero clashes between main system runs and the building structure. Figure 14 shows an image of the 3D model used in clash detection with systems shown in different colors. Drawing CM-004 shows renderings of the mechanical and cogeneration rooms after system coordination was completed.

Project Schedule

In order to determine the schedule, the school year start and end dates were used to figure out an overall project duration. The school year will end sometime in mid-June, and the new elementary school will need to be completed before another school-year begins, showing that the project should start in June and end in August. For project duration, this means the schedule can either be 14 months long or 28 months long. In order to save costs general conditions the team decided to make an efficient 14 month schedule. The project will begin in June 2013 and complete in August 2014. Figure 15 shows a general milestone schedule used to determine the durations of various activities throughout the construction process.

ID	Milestone	Completed by
1	Notice to Proceed	June 10, 2013
2	End of 2012/13 School Year	June, 2013
3	Demolition Complete	July-2013
4	Excavation Complete	July-2013
5	2013/14 School Year Begins	September 2013
6	Foundations Complete	October-2013
7	Top Out Steel	November-2013
8	Slab Placement Complete	December-2013
9	Precast Panels Complete	December-2013
10	Building Dry-In	January-2013
11	MEP Rough-In Complete	March-2014
12	MEP Complete	April-2014
13	End of 2013/14 School Year	June-2014
14	Finishes Complete	July-2014
15	Commissioning/Punchlist	July-2014
16	Substantial Completion	August 1, 2014
17	2014/15 School Year Begins	September 2014

Figure 15: Milestone schedule showing major systems and completion dates

In order to successfully complete the project in the 14 month schedule, there are several design features allowing for quick delivery. Façade work can take months to do and is heavily affected by weather. Using the precast façade greatly shortens the façade schedule and the work can be done regardless of temperature conditions. The mechanical system chosen will also quicken overhead MEP work. By having radiant ceiling panels which contain sprinklers, the contractors will simply need to raise the panel and connect branch piping.

Risks

With a tight schedule, there are many activities which are critical to the success of the project. One of the most important schedule items is building dry-in. It is crucial to get the building enclosed by the start of winter so workers can continue without being in the harsh winter temperatures. Keeping water out of the building is critical for MEP trades, since indoor equipment cannot get wet.

The project team will need to be aware of risks associated with the schedule. Sinkholes are a major risk to the project. Having a sinkhole open on the construction site could shut the entire site down until the problem is resolved, delaying construction exponentially. The remediation plan mentioned earlier will keep schedule losses as small as possible in the event of a sinkhole.

The project team and owners must also be aware of items which have a long lead time. The equipment with the longest lead times includes transformer which must be ordered 20 weeks ahead of time. Other critical lead time items include radiant ceiling panels and structural steel. The design team should be aware of these items and the submittal process has to be monitored to prevent delays. Critical building equipment lead times can be seen on page 29 of the Supporting Documents section of the report. Lastly, the crane usage on site is a major schedule risk. If the steel crane gets held up or delayed, all activities following steel will be held up. The steel subcontractor should know the date that steel must be completed in order to plan their erection process effectively. Utilizing the 4D phasing model will assist in relaying the schedule information to the erector.

Cost

The total building cost is estimated to be $21,344,312 which equates to $203.15 per square foot. The per-student cost is based off of 988 students in the school (26 per classroom) and tabulated to be $21,604 per student, which is below the national average for elementary schools of $24,000 per student (Moore, et al, 2012). This price includes all work from demolition of existing structures through completion of the new elementary school and the pool area underneath the gym.

Should the school district choose not to build the pool space, a credit of $2,300,000 will be given. A consequence of this is the greatly lowered efficiency of the cogeneration system due to waste heat not being used for pool water heating. In this event, there will be no excavation under the gym area, causing the west wing of the school to be on grade. Detailed alternate descriptions are on page 22 of the Supporting Documents. The ballistic glass alternate is an optional security feature for all first floor windows to be use ballistic glass. More security information can be seen in the Integration Narrative. These decisions must be made by March 1, 2013 to have no impact on schedule.

The general conditions breakout cost is $1,815,745 equating to 7% of the overall project cost, and the breakout price for the pool as stated before is $2,366,175. Demolition of the three existing structures on site, aside the existing elementary school, will cost $365,000. Table 2 shows the breakdown of prices by systems. An on-screen quantity takeoff assisted in efficiently obtaining quantities of steel members from the structural Revit file and a more detailed structural breakdown can be seen on page 27 of the Supporting Documents.

Category	% Projected	Cost	% Actual
Structure/Enclosure	31.00%	$5,742,009.72	29.96%
Interior	15.00%	$2,913,391.80	15.20%
Conveying	0.02%	$68,900.00	0.36%
Plumbing	23.50%	$4,564,313.82	23.82%
HVAC	13.00%	$2,524,939.56	13.18%
Fire Protection	2.48%	$436,620.32	2.28%
Electrical	14.00%	$2,719,165.68	14.19%
Equipment	1.00%	$194,226.12	1.01%
Subtotal	100.00%	$19,163,567	100.00%
Demolition		$365,000	
General Conditions		$1,815,745	
Total		**$21,344,312**	**Total Yearly energy savings: $80,625** 29% Under ASHRAE 90.1 Baseline
Cost/SF		**$203.15**	
No Pool Alternate		($2,300,000)	
No Pool or Cogen		($2,315,000)	
Ballistic Glass Alternate		$86,250	

Table 2: Systems breakdown of building costs including projected and actual percentages of total cost.

In order to compare the Reading Elementary School cost to other elementary schools which don't contain pools, the pool breakout price is taken out of the building cost, making the value $18,978,137. Altering the square footage of the building due to the pool being taken out gives the elementary school a square foot cost of $203.06 per square foot, above the national average of $181.00 per square foot, but in line with similar high performance schools (Moore, et al, 2012). Table 3 shows elementary various elementary schools and their costs per square foot which have been adjusted for time and location.

Name	Location	Cost/Square Ft.
River Crest Elementary School	Hudson, WI	$159.45
Carlton Elementary School	Salem, MA	$185.38
Gloria Marshall Elementary School	Houston, TX	$225.37
Edward Hynes Elementary School	New Orleans, LA	$210.23
Mt. Nittany Elementary School	State College, PA	$240.38
Average adjusted for 2013 in Reading		$201.30
Estimated Cost		$203.15

Table 3: Various adjusted elementary school costs per square foot averaged and adjusted for Reading, PA.

This table takes construction costs for recently built high-performance elementary schools and adjusts them for time and location, to be compared to construction costs in Reading. After finding an average square foot cost of $201.30, it can be seen that the estimated Reading Elementary School cost is $1.76 per square foot more than the average of the compared schools. Using the square footage of the proposed school, this amounts to an addition of $164,488 in cost. The additional cost is due to some of the innovative systems, but is a worthy expenditure since the Reading Elementary School will save the district $80,625 yearly due to energy savings.

In addition to construction of the new elementary school, the project team is proposing the renovation of the existing elementary school on site. This work can be completed after the new elementary school is constructed. The cost for renovating the existing school is estimated to be $1,732,000 or $125 per square foot and take 6 months to complete.

Conclusion

Throughout design of the Reading Elementary School, the construction team was able to evaluate their achievement of the goals listed earlier:

1. Build a better Reading community through construction and implementation of the school program
    - Prepared an efficient 14 month construction schedule, allowing completion over the course of one school year
    - Performed detailed cost analysis of all systems to guarantee short payback periods and savings
2. Design the elementary school to high-performance standards
    - Developed designs for prefabricated exterior wall and ceiling panels for efficient construction
    - Created an augmented reality, 3D and 4D models to enhance construction planning
3. Utilize an integrated design approach to maximize quality, efficiency, and value of the final built product
    - Prepared detailed constructability, risk and quality control assessments
    - Coordinated activities to make the best usage of production time on site

The project team feels that through energy savings, reduced maintenance costs and electric cogeneration, the cost of this new elementary school will be able to save the Reading School District money in the future, while delivering an innovative and cutting edge product the entire community can take pride in.

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Remediation Plans

Asbestos

Planning

1. Have the contractor/inspector clearly identify the form, condition, quantity and location of asbestos materials to be removed in the description of work?
2. Notify EPA 5days prior to commencement of work
3. Have contractor submit
    a. Asbestos Hazard Abatement plan (which includes…)
        i. Signature and seal of qualified inspector
        ii. Drawing of location, size, and detail of regulate areas
        iii. Air monitoring plan
        iv. Precise protective equipment used
        v. Detailed sequence of asbestos removal
        vi. Disposal plan
        vii. Wetting agent used
        viii. Emergency response plan
    b. Safety plan
    c. Certified testing laboratories (asbestos sampling)
    d. Equipment certification
    e. Name and location of certified waste disposal site
    f. Name and worker training certification (NESHAP)

Execution

Preparation

1. Inform all employees on site of asbestos removal
2. Post proof of training on site as well as adequate warning signs
3. Seal all opening with only one entry/exit allowed
4. Confirm all equipment meets plan submittal
    a. MSHA & NIOSH approved
    b. Air Source Grade D
    c. All equipment made by same manufacturer

5. *Removal*

1. Make sure material is treated with a wetting agent
2. Make sure all materials being placed in a metal drum lined with 6-mil plastic bag
3. Confirm bags are properly labeled with OSHA approved labels
4. Perform Daily air monitoring

5. *Disposal*

1. Have all waste, protective equipment and building materials contained in asbestos disposal
2. Confirm bag label have waste origin designated
3. Make sure all transport vehicles have properly posted danger signs

Acceptance/Monitoring

1. Confirm monitoring reveals acceptable clearance concentration

2. Receive copies of all appropriate environmental monitoring documents
    a. Disposal documentation
3. Forward all documentation to DEP for confirmation

Information Provided by: ("Managing Asbestos Abatement for Demolition Contracts by Naval Facilities Engineering Service Center")

Lead Soil

1. Test Bore excavation areas and perform laboratory analysis, utilizing a grid method for test areas
    a. Field test bores for lead, send positive tests to a lab for further analysis.
    b. Close contaminated soil areas until remediation efforts are complete.
2. Worker training
3. Contaminated soils are to be loaded into designated trucks
    a. Trucks are to be cleaned prior to exiting site to ensure further contamination doesn't exist.
    b. Wash basins are to be separated from the rest of the site and monitored by qualified personnel.
4. Contaminated soils are to be immediately taken to a remediation center
5. Testing and further excavation should continue in contaminated areas until no more lead content exists.
6. Backfill excavated areas if necessary with specified backfill type.

Information Provided by: (EPA), (RW Collins), (Empire State Development)

Sinkholes

1. Understanding Existing
    a. Site Location
        i. There are signs of sinkholes in surrounding areas
    b. Subsurface Conditions
        i. Unconsolidated coal ash, glass, other poor fill
2. Address Potential Sinkholes:
    a. Types
        i. Solution Sinkhole – Form Over Time when bedrock erodes.
        ii. Subsidence Sinkholes – Occurs when Sand replaces the area where limestone dissolved. Takes a long period of time
        iii. Collapse Sinkholes – Occurs from rapid heavy load dropped above it
            (1) In the event you have really thick clay or even a cohesive rock unit above the limestone, the collapse tends to be pretty sudden. Essentially when the adhesive properties of the clay can no longer support its weight, it will fall into the limestone void beneath it. This can happen in a matter of seconds, but may take hours or even days.
    b. Signs
        i. There will be a depression in the ground
            (1) Perform Site Walks to discover any possible sinkhole concerns
                (a) 2 times a week by the Geotechnical Engineer
    c. Addressing
        i. Call Insurance
        ii. Get expert to inspect the damage(Geotechnical Engineer)
            (1) Determine structural integrity of soil
            (2) Test bore the soil conditions if necessary
        iii. Prevent further disruption to the runoff that may concentrate flow towards sinkholes
3. Remediation
    a. Have Geotechnical Engineer on site
        i. Backfill
            (1) Backfill an initial layer of engineered soil
            (2) Subsequent backfill placement
        ii. Subsurface grouting Program

(1) Identify void spaces in soil and address points of Subsurface grouting
    (a) Primary
    (b) Secondary
    (c) Tertiary
(2) Perform Subsurface Grouting in sequential order primary to secondary as determined by the Geotechnical engineer
    (a) It is not recommended to grout the center of the sinkhole with the risk of destabilization
        (i) Until pressure increases above a certain PSI as determined by the Geotechnical Engineer

iii. Post Remediation Monitoring
(1) Visual Monitoring will be performed to determine safety of addressed sinkhole
(2) Technical monitoring will be installed to determine changes in elevation if deemed necessary by engineer

4. Protection Policy:
   a. Sinkhole Training
      i. Educating on the different types and the potential hazards. Inform them of ways to keep safe if a problem is noticed
      ii. Have all workers leave the area affected to a safe distance immediately
      iii. Contractor to block off area around the depressed soil as determined by the geotechnical engineer
      iv. Manned Soil spreading equipment must remain outside of the area designated by the Geotechnical Engineer
      v. Provide all proper signage prepared in case a sinkhole has been discovered
   b. Sinkhole insurance
      i. Used to protect against remediation cost
   c. Construction debris can cause sinkholes in the future
      i. Enforce this aspect during construction

Information Provided by: (Kochanov), (Rembco Geotechnical Contractors)

Subsurface Grouting courtesy of:
http://www.foundationservicescf.com/uploads/images/sinkhole-lb-large.jpg

Façade Estimate

Precast (RS Means 2013)					
Total SF	Material	Labor	Equipment	Total	EXT.
30500	$47.00	$2.50	$1.50	$51.00	$1,555,500.00
adjusted for Prevailing	$47.00	$5.00	$1.50	$53.50	$1,631,750.00
Hours/SF	Total Duration			Hours/SF	
0.055	24.0625	days		0.3	

Comparative Brick on Stud Wall Composition	
Brick	Plywood sheathing
Joint backer rod	Building paper-asphalt felt
Sealant	Insulation
Wall ties	Flashing
Shelf angle	Gyp board
Partitions	Tape finish

Brick On Stud (RS Means 2013)					
	Material	Labor	Equipment	Total	EXT
Brick	$7.75	$17.00	$1.00	$25.75	
Gyp	$0.40	$1.50	$0.15	$2.05	
Total	$8.15	$18.50	$1.15	$27.80	$847,900.00
adjusted for Prevailing	$8.15	$37.00	$1.15	$46.30	$1,412,150.00
		Total Duration			
		131.25	Days		
		26.25	Weeks		
		6.5625	months		

Pool Estimate

Adding in Basement (RS Means 2013)				
Pool	**Unit**	**Quantity**	**Cost**	**Total**
Plumbing	SF	11500	$16	$184,000
Electrical	SF	11500	$20	$230,000
MEP Equipment	SF	11500	$0	$0
MEP Distribution	SF	11500	$17	$195,500
TOTAL				**$609,500**
Difference to Design	**Unit**	**Quantity**	**Cost**	**Total**
piles	Cluster	5	$12,775	$63,875
Pile caps	EA	5	$830	$4,150
Grade Beam	LF	0	$105	$0
Excavation	SF	13000	$17	$221,000
Shoring	LF	220	$1,304	$286,902
Foundation Wall	LF	470	$460	$216,200
Beam-Steel	SF	11608	$10	$116,080
Column-Steel	VLF	580	$120	$69,600
Added slab on metal deck	SF	11608	$15	$174,120
Windows	SF	-1350	$26	-$34,965
Stairs	EA	1	$20,000	$20,000
Stair & Ramp	EA	1	$12,500	$12,500
TOTAL				**$1,149,462**
Pool Requirements	**Unit**	**Quantity**	**Cost**	**Total**
Beam-Steel	SF	11608	$10	$116,080
Roof Construction	SF	11608	$15	$174,120
Windows	SF	270	$26	$6,993
Interior Walls-block	SF	3200	$15	$48,000
Interior Wall-stud	SF	2400	$6	$14,400
Floor coverage	SF	11200	$11	$123,200
Ceiling-drywall	SF	5000	$5	$22,500
Ceiling-acoustical	SF	6200	$5	$32,860
Door Interior	EA	7	$1,000	$7,000
Toilet partitions	EA	5	$800	$4,000
Entrance screen	EA	2	$340	$680
Urinal screen	EA	2	$365	$730
Shower Partitions	EA	6	$1,150	$6,900
Lockers	EA	70	$125	$8,750
Accessories	Per Toilet	6	$500	$3,000
Casework	Project	1	$10,000	$10,000
Bleachers	EA	1	$15,000	$15,000
Excavation	SF	13000	$1	$13,000
TOTAL				**$607,213**
Total Cost				$2,366,175
Cost/SF				$204

Alternates

	Base Design – Integrated Pool and Cogen. Design	Option – No pool, Yes on Cogeneration system	Option – No pool, No Cogeneration system
Integrated Pool?	Yes	No	No
Cogen. system?	Yes	Yes	No
Cost	Baseline Cost	Credit of $2,300,000	Credit of $2,315,000
Comments	Most integrated design choice. Full reported savings from CHP system. Gives community access to swimming pool without increasing the building footprint.	Exhaust heat from the CHP system can be redirected to existing school on site. Full savings from the CHP system will be spread out over the newly built school and existing elementary school. School district has the option to build an above ground pool in the future. The community garden is still inclusive as part of the base contract.	Mechanical equipment (boilers, pumps, etc.) is already designed to handle school loads without operation of CHP system. Thus, full mechanical redesign is not necessary. Only a few changes in basement mechanical room layout will take place. CHP system savings will be lost with this option and a generator will be necessary.

Ballistic Glass Alternate			
Window Type	**Cost/SF**	**Cost**	**Price Difference**
Low-e Double Pane	$40	$150,000	$86,250
Ballistic Glass	$63	$236,250	
http://www.lascointl.com/category/Bullet-Resistant-Glass-4			
http://www.buildings.com/tabid/3334/ArticleID/14300/Default.aspx			

Mechanical System Estimate

Radiant Floor Cost (http://www.radiantec.com/pricing/ballpark-estimates.php)		
Floor	Radiant Floor SF	
First	21690	
Second	27004	
Third	20090	
Total	68784	
Tube Size	Cost/SF	Cost
7/8" to 1/2"	$0.50	$34,392
# of Zones	Cost/Zone	Cost
First 2	$1,100.00	$2,200.00
First 2	$1,250.00	$2,500.00
Other 70	$300.00	$21,000.00
Other 70	$400.00	$28,000.00
Equipment	Price	
Pump	$18,425	
Boiler	$306,000 *assume same cost as chiller	
TOTAL Range		
From	To	
$382,017.00	$389,317.00	

Cooled Ceiling and DOAS Cost (http://doas-radiant.psu.edu/Journal2.pdf)	
Floor	Cooled Ceiling SF
First	21690
Second	27004
Third	20090
TOTAL	68784
Cost/Sf of panel area (70% total area)	$13.00
Total Cost	$625,934
Ductwork	
Cost/SF	$1
Total Cost	$68,784
Equipment	Price (assumed)
Chiller	$306,000
Pump	$18,425
AHU	$100,000
Cooled Cost	$1,119,143

TOTAL Radiant Mechanical Cost		
From		To
$1,501,160		$1,508,460
AVG		$1,504,810
Per SF		
$21.82		$21.93
AVG		$21.88
Savings (Rounded)		$22,000 per year
Compare: Rooftop Multizone Unit System		
$19.70/SF		$1,355,045
Total Price Difference	$149,766	
At $22,000 per year, return on investment		6.81 years

Microturbine Savings and Grant Information

Month	Baseline Monthly Cost	Design Monthly Cost
January	$17,340.81	$12,897.96
February	$17,340.81	$12,897.96
March	$17,340.81	$12,897.96
April	$19,130.13	$14,272.20
May	$17,490.50	$12,796.53
June	$19,133.20	$14,274.97
July	$16,462.48	$12,041.98
August	$19,576.06	$14,574.32
September	$21,293.69	$16,120.19
October	$19,598.02	$14,693.31
November	$17,340.81	$12,897.96
December	$17,340.81	$12,897.96
Total	$219,388.12	$163,263.31
Gross Annual Savings		$56,124.81

Project	Location	Microturbine kW	Grant Amount
Clarion University Science and Technology Center	Clarion, PA	65	$163,996
York Wastewater Treatment Plant	York, PA	1600	$500,000
Philadelphia Gas Works	Philadelphia, PA	200	$465,000

Courtesy of: (Lello, 2011), (Pearce, nd), (McCottry, 2009)

Demolition Estimate

Estimation Info (RS Means 2013)			
Structural Demolition	Cost/CF	Quantities	Cost
Mixed Structure	$0.31	372919	$115,604.79
6" Concrete SOG	$6.22	26637	$165,682.44
Foundation Walls	$2.51	16046	$40,276.30
Footings	$23.20	1885	$43,741.67
TOTAL			$365,305.20

Building	Building 1	Building 2	Building 3	Total
Building CF	200977	53014	118927	372919
Floor SF	14355	3787	8495	26637
Approximate Wall	6713	3705	5628	16046
Approximate Footing	921	361	603	1885

General Conditions Estimate

General Conditions (RS Means 2013)				
	Unit	Quantity	Cost	Total
Project Exec	Wk	4	$3,700	$14,800
Project Manager	Wk	18	$3,350	$60,300
Superintendent	Wk	50	$3,100	$155,000
Field Engineer	Wk	50	$2,050	$102,500
Project Assistant	Wk	35	$775	$27,125
Builders risk	%project	22000000	$0	$44,000
Bond-performance	%project	22000000	$0	$132,000
Temp Heat	Wk	14	$37,400	$523,600
Temp Lighting	Wk	20	$31,900	$638,000
Temp Power	Wk	0	$88,000	$0
Trailer(dbl wide)	mth	14	$600	$8,400
Storage Box	mth	9	$82	$738
Office Equipment	mth	14	$220	$3,080
Office Supplies	mth	14	$83	$1,162
Ele,Light, Telecom	mth	14	$300	$4,200
Crane (12 ton)	Day	0	$1,675	$0
Crane (40 ton)	Day	0	$1,925	$0
Crane (100 ton)	Day	0	$3,675	$0
Mobilize/Demo	EA	0	$750	$0
Small Tools	project	1	$10,000	$10,000
Clean up	Project	1	$10,340	$10,340
Waste Removal	CY	5000	$15	$75,000
Signage	Project	1	$500	$500
Surveying	days	5	$1,000	$5,000
TOTAL				$1,815,745
Cost per month				$129,696
% of Building Cost				7%

Assumptions	
Category	Responsible Party
worker comp	subs
permits	owner
power	subs
Protective equipment	subs
Crane	subs
Roads	subs
railing	subs
Commissioning	subs
Surveying	Subs
Testing	owner
swing staging	subs
Fencing	subs

Estimate Breakdown

Structure & Enclosure (RS Means 2013)						
Item	**Quantity**	**Unit**	**MAT**	**INST**	**TOT**	**Total**
Piles	112	Grouping	$530.00	$675.00	$1,205.00	$134,960.00
Grade Beam	1800	LF	$56.00	$78.00	$134.00	$241,200.00
SOG	21560.00	SF	$3.00	$3.16	$6.16	$132,809.60
Excavation 14'	9952	SF		$9.00	$9.00	$89,568.00
20'	11608	SF		$11.63	$11.63	$135,001.04
Basement Wall - 14'	650	LF	$88.50	$197.00	$285.50	$185,575.00
20'	525	LF	$126.56	$281.71	$408.27	$214,339.13
Steel Columns						$479,524.00
Beams						$1,006,070.78
Floor	83507.00	SF				$509,159
Roof-Struct	34951	SF	$6.00	$2.00	$8.00	$279,608.00
GreenRoof	6000	SF	$2.00	$2.00	$4.00	$24,000.00
EPDM	28951	SF	$1.25	$1.00	$2.25	$65,139.75
Flashing	1216	LF	$14.00	$10.00	$24.00	$29,184.00
Hatches	4	EA	$980.00	$242.00	$1,222.00	$4,888.00
Precast	30503.2	SF	-	-	$51.00	$1,555,663.20
Window	360	EA	$510.00	$305.00	$815.00	$293,400.00
Exterior Door (3')	4	EA	$2,025.00	$1,025.00	$3,050.00	$12,200.00
6'	8	EA	$3,925.00	$2,050.00	$5,975.00	$47,800.00
Elevator	1	EA	$51,500.00	$17,400.00	$68,900.00	$68,900.00
Pool Equip. Costs	1	Unit			$300,000.00	$300,000.00

Beams				
Type	**Size**	**Length**	**Cost/Ft**	**Cost**
W	W8x10	1860.61	$25.50	$47,445.61
W	W10X12	518.31	$28.50	$14,771.94
W	W10X19	97.30	$40.00	$3,891.89
W	W12X14	1186.27	$29.00	$34,401.96
W	W12X16	582.56	$31.00	$18,059.27
W	W12X19	855.75	$37.00	$31,662.83
W	W12X22	445.37	$40.50	$18,037.41
W	W12X26	163.24	$46.50	$7,590.69
W	W14X22	2267.65	$42.00	$95,241.21
W	W14X26	112.11	$46.00	$5,157.02
W	W14X30	268.45	$52.50	$14,093.68
W	W16X26	770.96	$46.00	$35,463.96
W	W16X31	2303.74	$54.00	$124,402.06
W	W16X40	107.28	$68.50	$7,348.52

W	W16X50	88.78	$83.50	$7,413.05
W	W16X57	29.59	$90.00	$2,663.44
W	W18X35	1709.24	$62.00	$105,973.16
W	W18X40	404.80	$62.00	$25,097.37
W	W18X60	25.51	$100.00	$2,551.34
W	W21X44	713.62	$74.50	$53,165.03
W	W21X48	449.16	$79.00	$35,483.83
W	W21X55	31.51	$90.00	$2,836.02
W	W21X62	128.05	$102.00	$13,060.97
W	W21X73	31.51	$117.00	$3,686.74
W	W24X55	570.06	$90.50	$51,590.43
W	W24X62	29.59	$102.00	$3,018.57
W	W24X68	496.90	$111.00	$55,156.40
W	W27X146	20.50	$228.00	$4,674.00
W	W27X84	102.50	$134.00	$13,735.00
Cellular Beam	LB36x5576	544.50	$250.00	$136,125.45
Cellular Beam	LB21X2226	61.50	$150.00	$9,225.27
VG Joist Girder	48VG	242.00	$57.00	$13,794.00
K series Joist	20K3	102.50	$11.10	$1,137.75
K series Joist	16K3	799.50	$10.15	$8,114.93
TOTAL				**$1,006,070.78**

Columns				
Type	**Size**	**Length**	**Cost/Ft**	**Cost**
W	10x17	39	$33.00	$1,287.00
W	10x33	3389	$61.50	$208,423.50
W	10x39	290	$70.00	$20,300.00
W	10x45	36	$85.50	$3,078.00
W	10x49	503	$85.50	$43,006.50
W	10x54	47	$89.50	$4,206.50
W	10x77	22	$97.00	$2,134.00
W	12x19	21	$35.00	$735.00
W	12x26	102	$46.25	$4,717.50
W	12x35	86	$60.50	$5,203.00
W	12x40	42	$67.00	$2,814.00
W	12X45	70	$72.00	$5,040.00
W	12x50	24	$84.00	$2,016.00
W	12x53	28	$87.00	$2,436.00
W	12x58	96	$96.00	$9,216.00
W	12x72	27	$119.00	$3,213.00
W	12x79	11	$130.00	$1,430.00
W	14x159	14	$275.00	$3,850.00
W	14x176	11	$290.00	$3,190.00

W	14x22	44	$40.00	$1,760.00
W	14x43	28	$72.50	$2,030.00
W	16x31	79	$54.00	$4,266.00
W	16x50	30	$83.50	$2,505.00
W	16x57	57	$90.00	$5,130.00
W	18x60	86	$100.00	$8,600.00
W	21x44	75	$74.50	$5,587.50
W	21x48	30	$83.50	$2,505.00
W	21x73	53	$120.00	$6,360.00
W	24x55	61	$90.50	$5,520.50
W	27x146	60	$228.00	$13,680.00
W	27x84	40	$134.00	$5,360.00
HSS	16x.25	121	$100.00	$12,100.00
HSS	16x.312	40	$115.00	$4,600.00
HSS	4.5x4.5x.375	147	$35.00	$5,145.00
HSS	5.5x5.5x.375	315	$37.00	$11,655.00
HSS	5.5x5.5x5/16	365	$41.00	$14,965.00
HSS	5x5x.375	360	$46.00	$16,560.00
HSS	5x5x.5	28	$48.00	$1,344.00
HSS	5x5x5/16	150	$60.00	$9,000.00
HSS	6x6x.375	116	$40.00	$4,640.00
HSS	6x6x.5	33	$49.00	$1,617.00
HSS	6x6x.625	33	$57.00	$1,881.00
HSS	6x6x5/16	93	$69.00	$6,417.00
TOTAL				**$479,524.00**

Equipment Lead Times

Equipment	Lead Time (weeks)
Microturbine	12
Façade Panel	8
Lighting	6
Switchgear	6
Transformer	20
Pumps	8
Boilers	6
Cellular Beams	18
Ceiling Panel	16
Chiller	6
Heat Exchanger	8
Steel	14
Glazing	4
Air Handling Unit	12

Mechanical and Electrical Equipment Lists

Mechanical Equipment List				
Air Handling Units				
Name Tag	**Design Airflow Rate (CFM)**	**Fan Size (kW)**	**Cooling Coil Capacity (Tons)**	**Heating Coil Capacity (MBH)**
1-West	10,800	12.23	34.02	583.2
2-Central	13,000	16.41	40.95	702
3-East	9,200	6.71	28.98	496.8
4-Community	17,800	5.97	56.07	961.2
5-Pool	8,000	5.97	25.2	432
Chillers				
Name Tag	**Served Loads**	**Compressor Type**	**Capacity (Tons)**	**Heat Rejection**
CH-1	Main AHU Coils	Screw	200	Water-Cooled Condenser
CH-2	Radiant Chilled Ceiling Panels	Screw	80	Water-Cooled Condenser
Chilled Water Pumps				
Name Tag	**System Served**	**Type**	**Design Flow Rate (GPM)**	**Design Head (Ft H2O)**
CHWP1-01	Main AHU Coils	Centrifugal		
CHWP1-02	Main AHU Coils	Centrifugal		
CHWP2-01	Radiant Chilled Ceiling Panels	Centrifugal	30	
CHWP2-02	Radiant Chilled Ceiling Panels	Centrifugal	30	
CHWP2-03	Radiant Chilled Ceiling Panels	Centrifugal	30	
Rooftop Condensers				
Name Tag	**Chiller Served**	**Type**	**Capacity (Tons)**	
CD-1	CH-1	Water	250	
CD-2	CH-2	Water	100	
Condenser Water Pumps				
Name Tag	**Chiller Served**	**Type**	**Design Flow Rate (GPM)**	**Design Head (Ft H2O)**
CWP1-01	CH-1	Vertical Turbine		
CWP1-02	CH-1	Vertical Turbine		
CWP2-01	CH-2	Vertical Turbine		
CWP2-02	CH-2	Vertical		

		Turbine		
Cogeneration Sources				
Name Tag	**Type**	**Fuel Sources**	**Electric Power Output (kW)**	**Net Heat Rate (Btu/kWh)**
CHP-01	Natural Gas Microturbine	Natural Gas, Propane	65	11,800
CHP-02	Natural Gas Microturbine	Natural Gas, Propane	65	11,800
CHP-03	Natural Gas Microturbine	Natural Gas, Propane	65	11,800
CHP-04	Natural Gas Microturbine	Natural Gas, Propane	65	11,800
Heat Exchangers				
Name Tag	**Type**	**Size (SF)**		
HTX-01	Shell and Tube	260		
HTX-02	Shell and Tube	260		
HTX-03	Shell and Tube	85		
Boilers				
Name Tag	**System Served**	**Fuel Source**	**Capacity (MBH)**	
B-1	Main AHU Coils	Natural Gas	900	
B-2	Main AHU Coils	Natural Gas	900	
B-3	Radiant Underfloor Slab	Natural Gas	1000	
Hot Water Pumps				
Name Tag	**Boiler(s) Served**	**Type**	**Design Flow Rate (GPM)**	**Design Head (Ft H2O)**
HWP1-01	B-1, B-2	Centrifugal		
HWP1-02	B-1, B-2	Centrifugal		
HWP2-01	B-3	Centrifugal	20	
HWP2-02	B-3	Centrifugal	20	
HWP2-03	B-3	Centrifugal	20	
Pool Equipment				
Name Tag	**Type**			
Pool-1	Sand Filter			
Pool-2	Sand Filter			
Pool-3	Pump			
Pool-4	Pump			

Electrical Equipment		
Name	**Size**	**Quantity**
480/277V Panel Single Tub	100A	8
208/120V Panel Double Tub	225A	7
Distribution Panel	800A	3
Automatic Transfer Switch	800A	2
Transformer Substation	750 kVA	1
(includes breakers and switchgear)		
Transformer	45 kVA	4
Transformer	75 kVA	2
Duplex Receptacle		400
Wiremold Raceway	18 foot sections	40
(outlets on 12" centers)		
Quad Receptacle/Data Floor Box		125
Data Outlet		75
SmartBoard 685ix		50
Wireless Access Point		50
Pendant Hung Speaker		200
(4 per classroom)		
Fire Alarm Speaker/Strobe		75
Fire Alarm Pull Station		15

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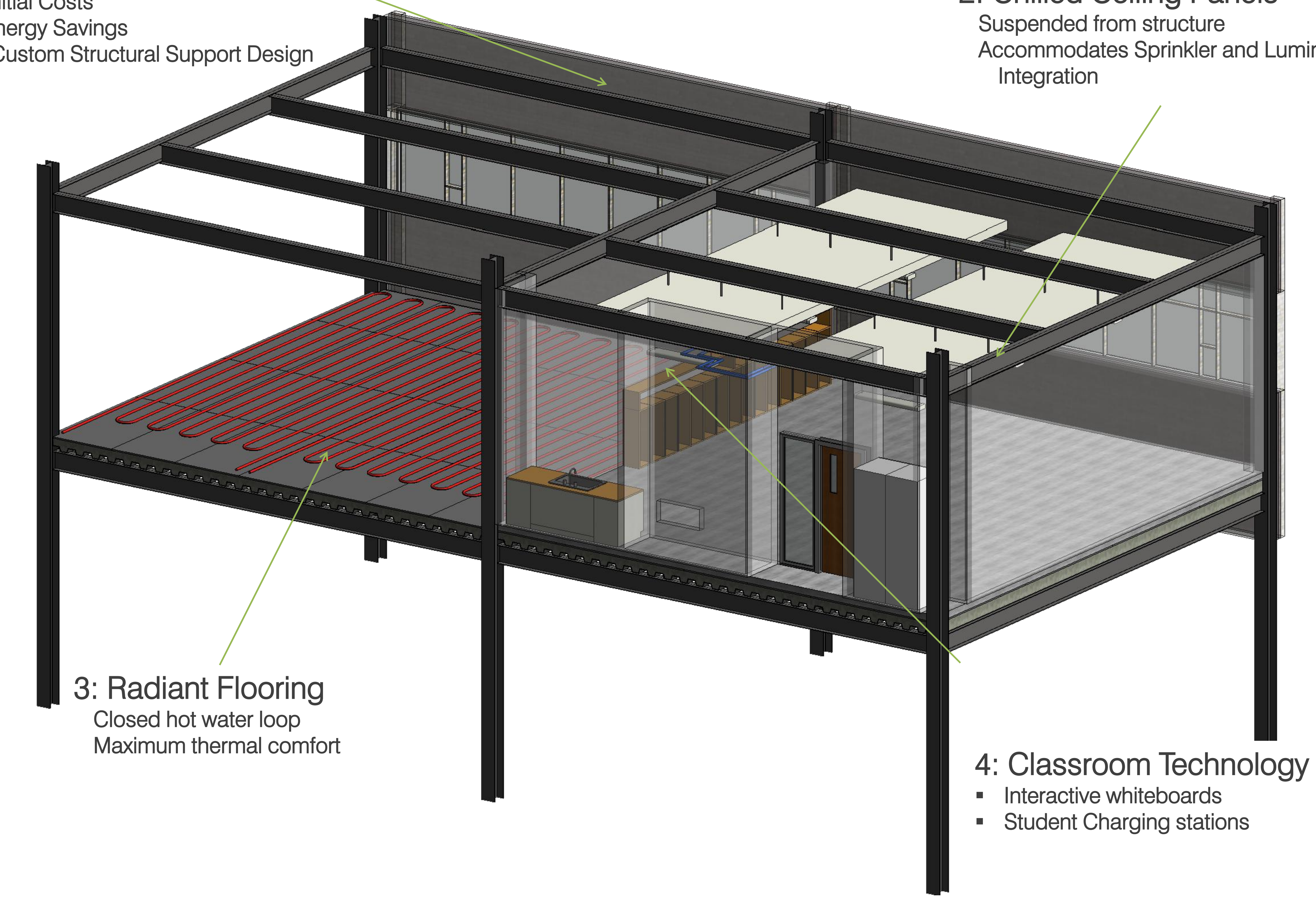
Classroom, Pool and Roof Detail

Classroom Detail

1: Prefabricated Panels
- Reduces Schedule
- Mitigates Initial Costs
- Provides Energy Savings
- Allows for Custom Structural Support Design

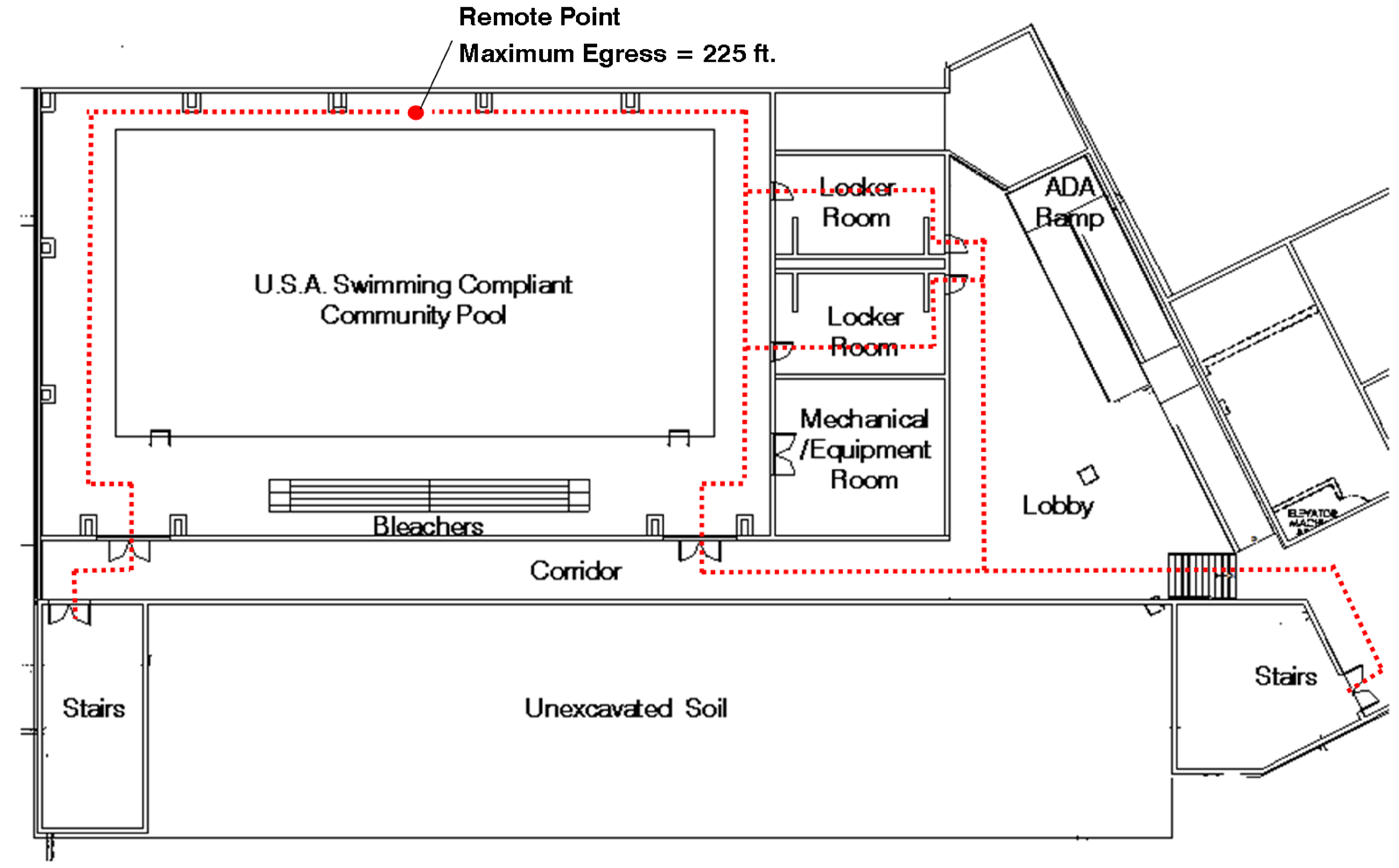
2: Chilled Ceiling Panels
- Suspended from structure
- Accommodates Sprinkler and Luminaire Integration



3: Radiant Flooring
- Closed hot water loop
- Maximum thermal comfort

4: Classroom Technology
- Interactive whiteboards
- Student Charging stations

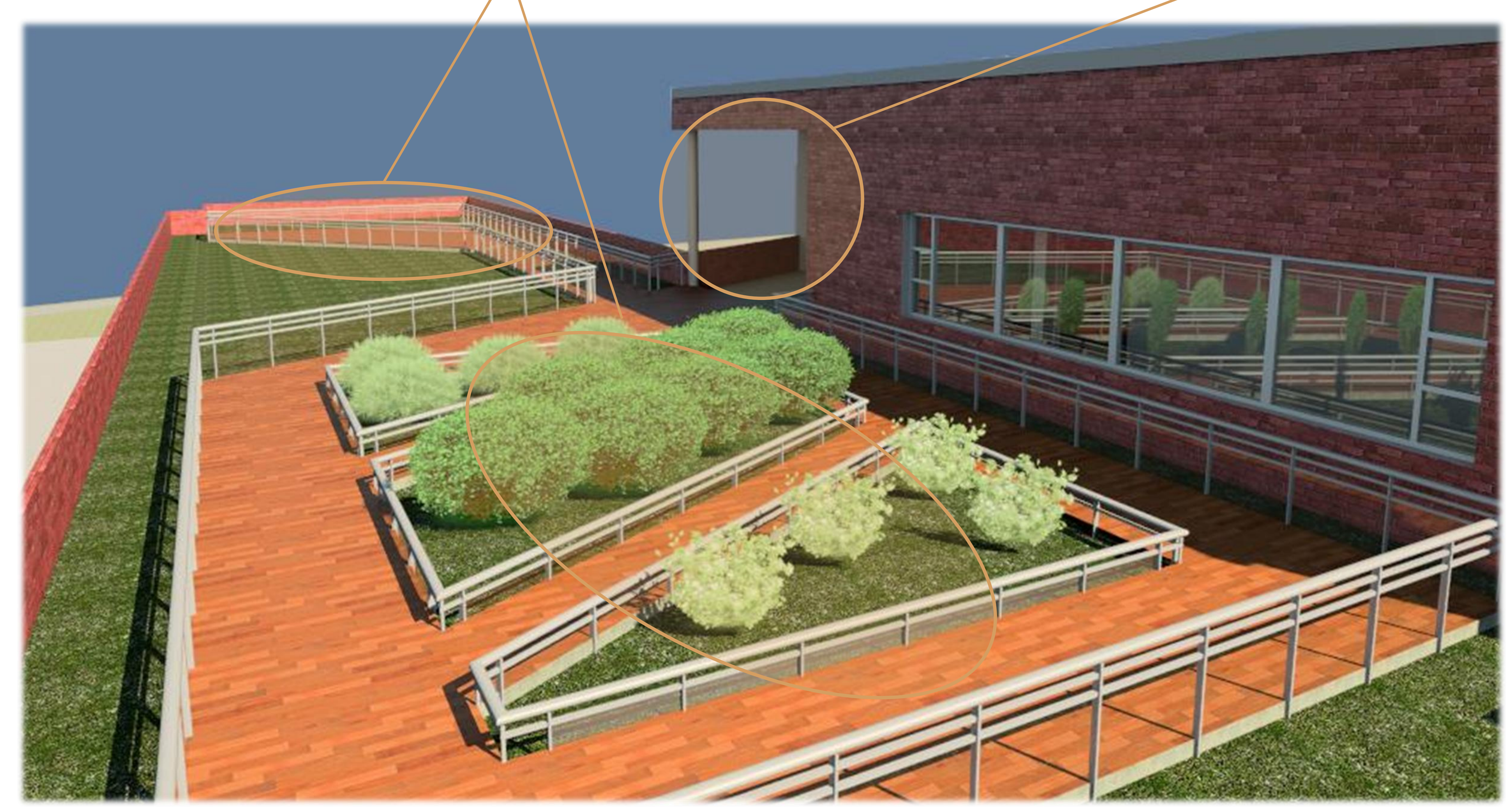
Pool Layout/Egress

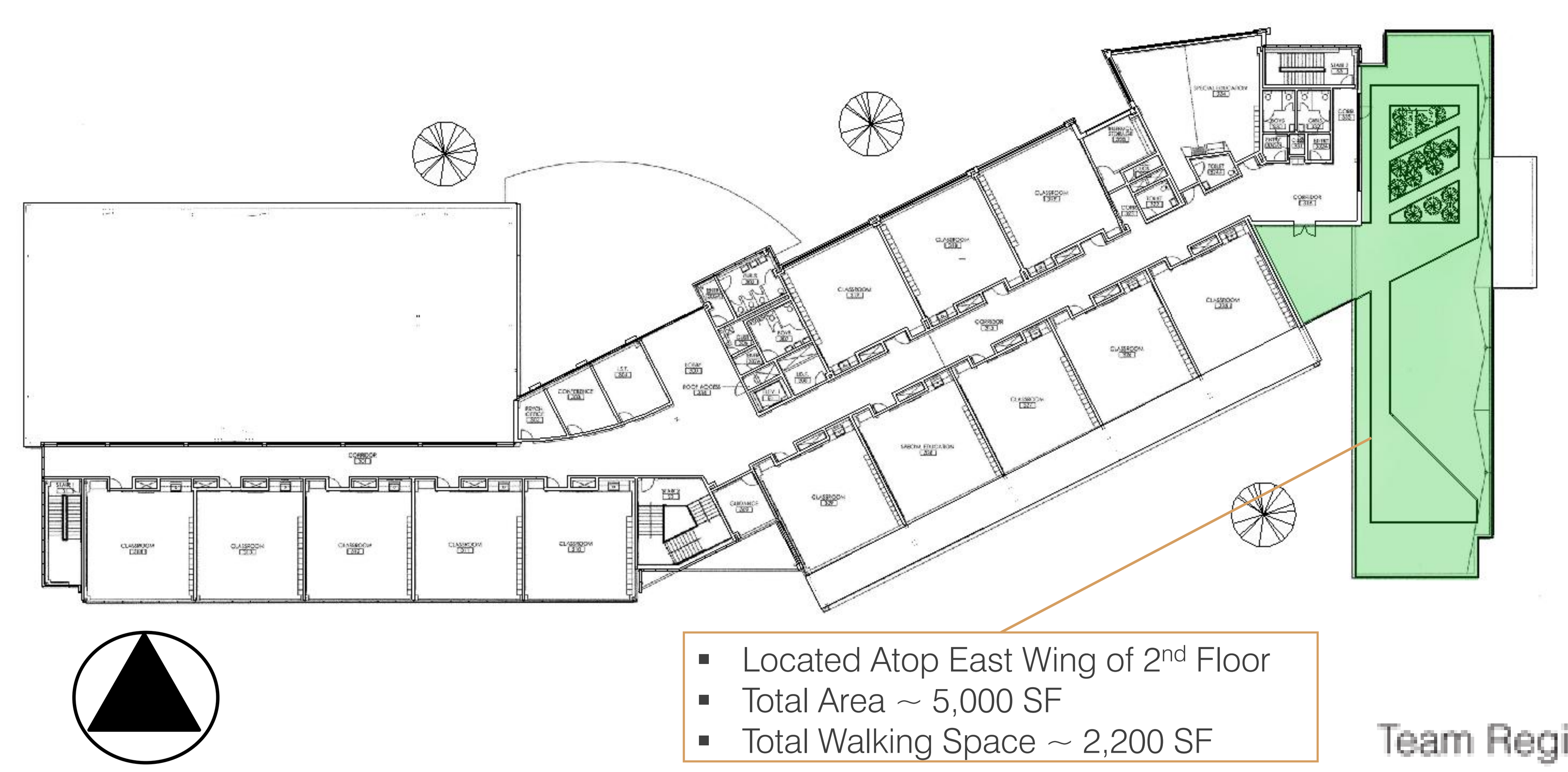


Green Roof Detail

- One Part Classroom Garden
- One Part Outdoor Auditorium Space

- Access From Third Floor
- Not Available to the Public





- Located Atop East Wing of 2nd Floor
- Total Area ~ 5,000 SF
- Total Walking Space ~ 2,200 SF

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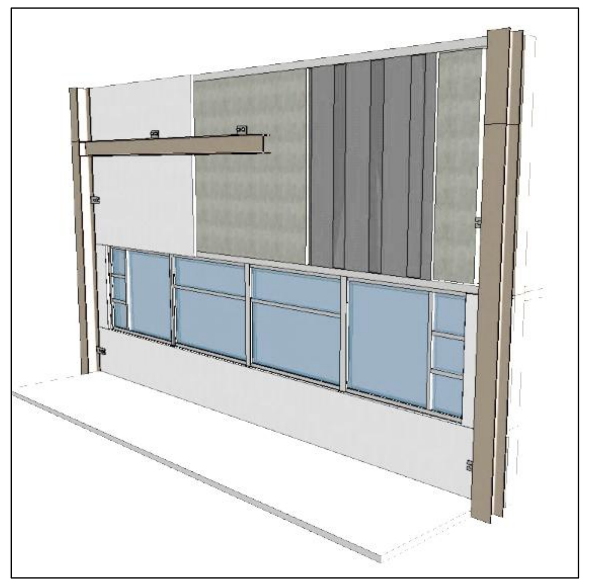
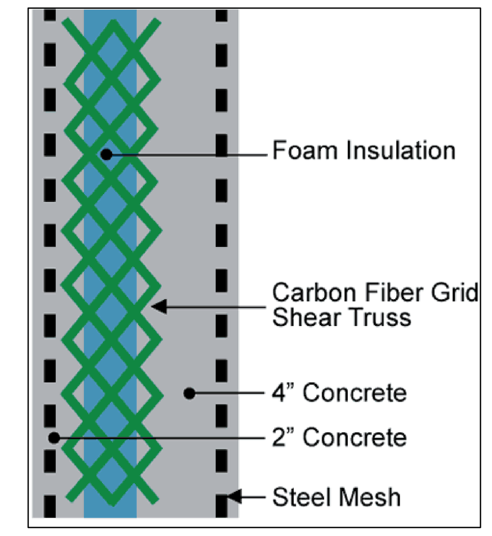
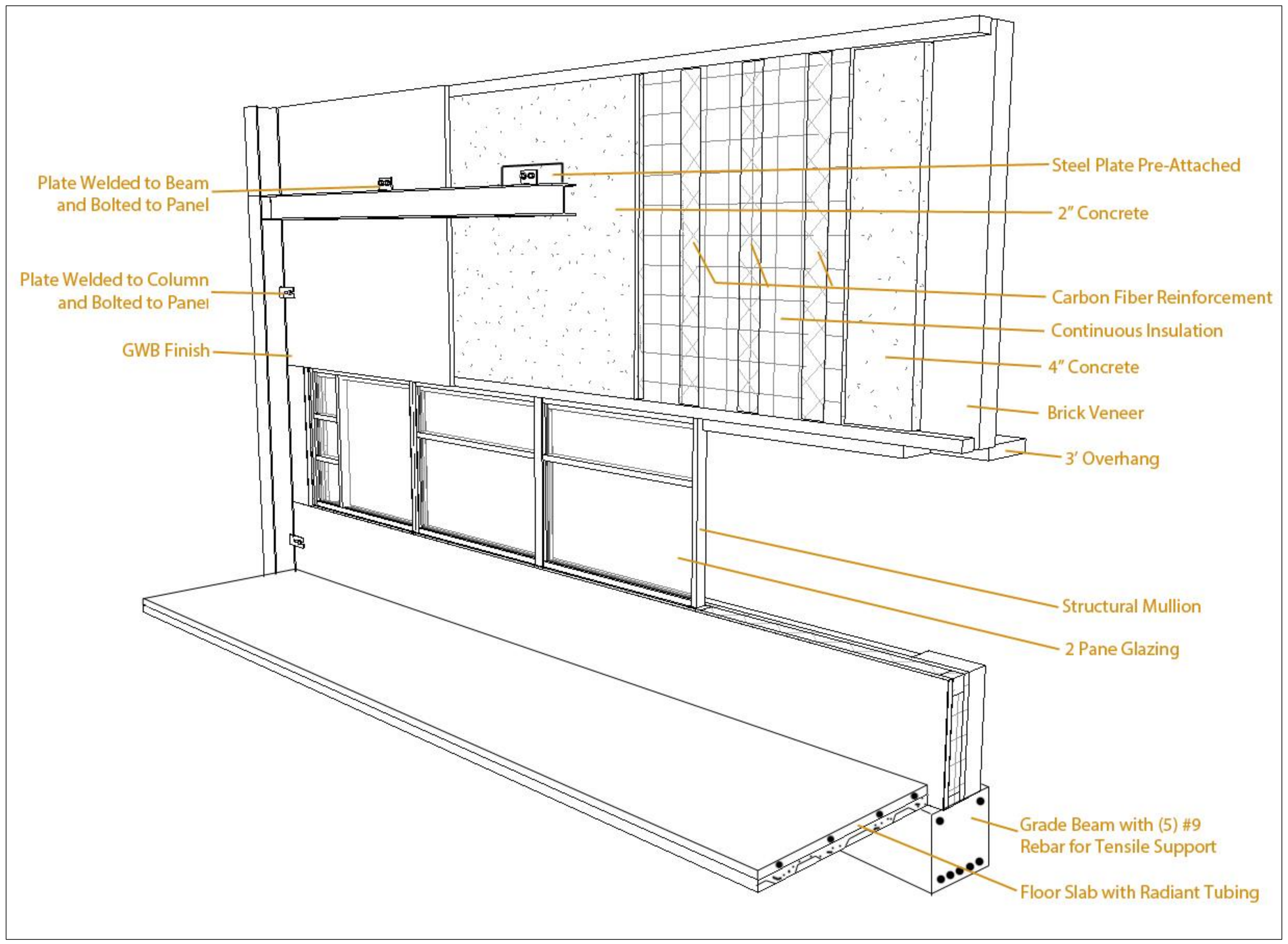
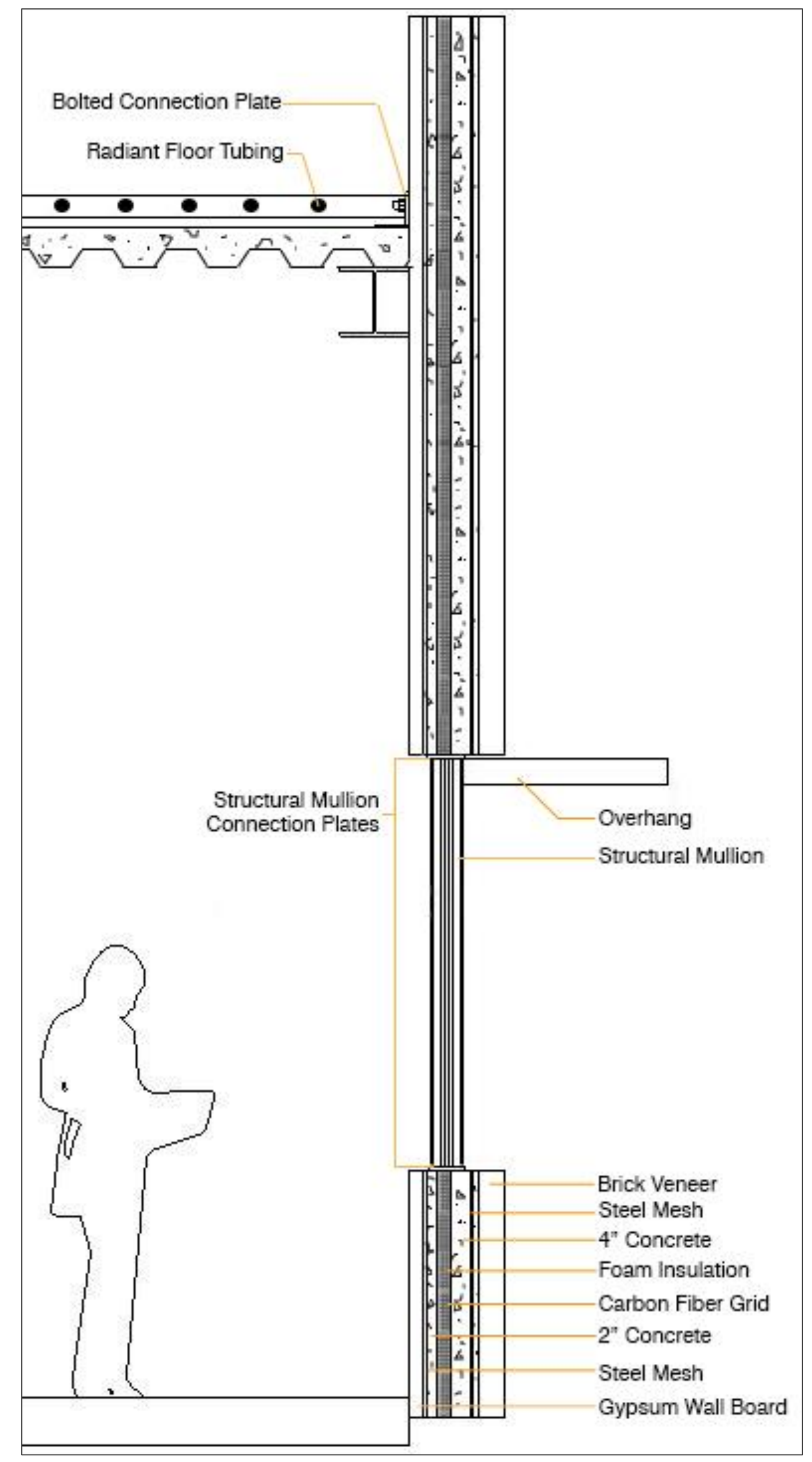




Precast panel cross section courtesy of http://www.structuremag.org/article.aspx?articleID=436





Façade Panel Detail

CM-002

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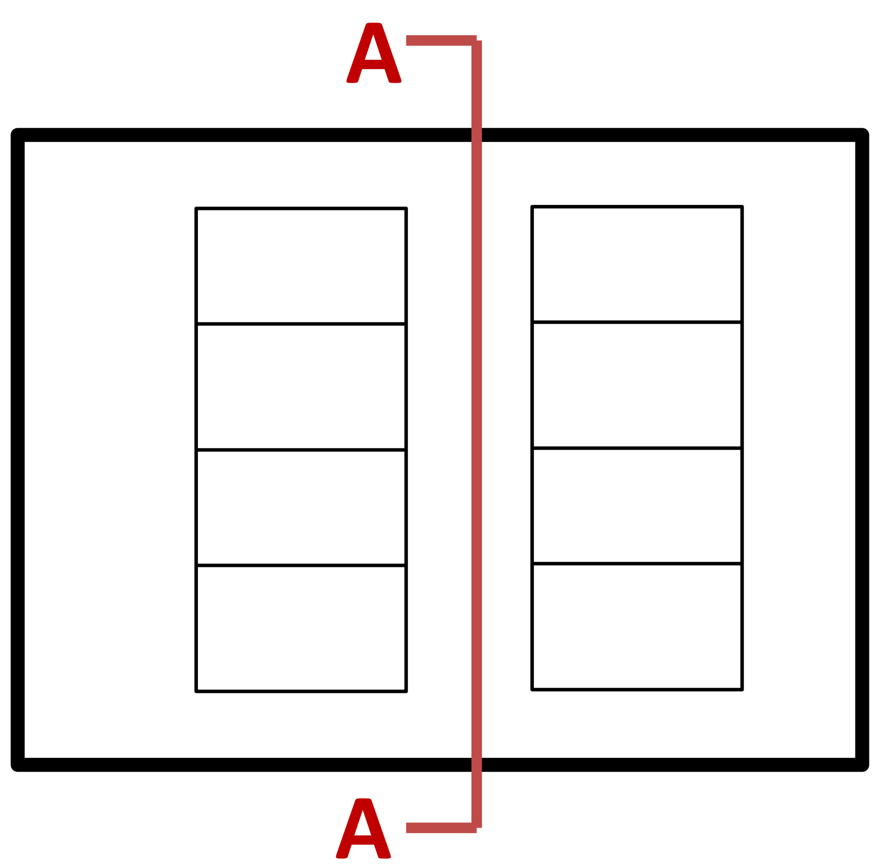
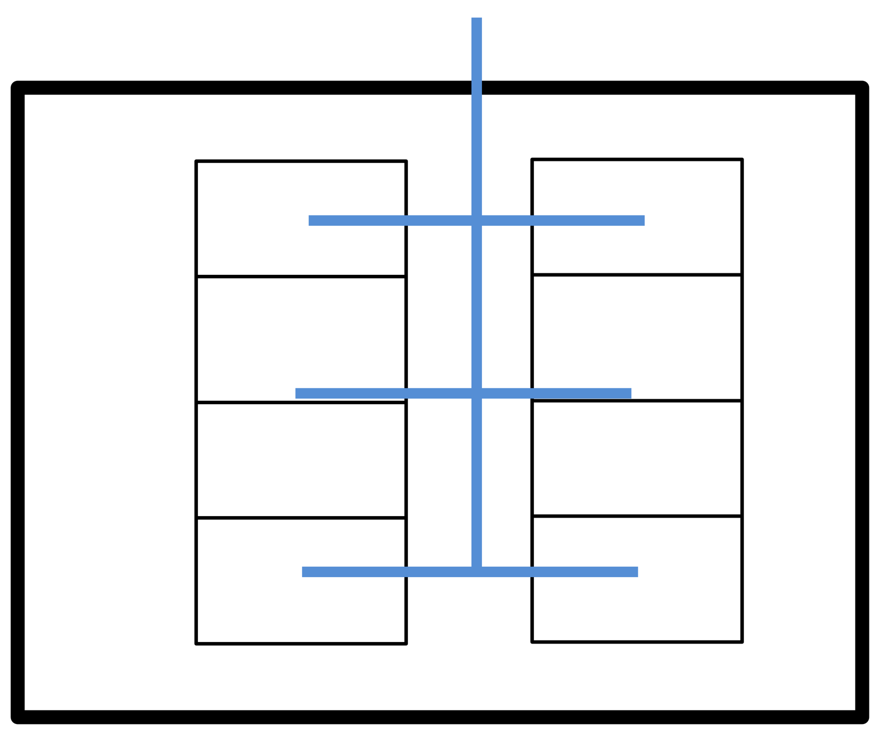
Ceiling Panel Detail



Room Front

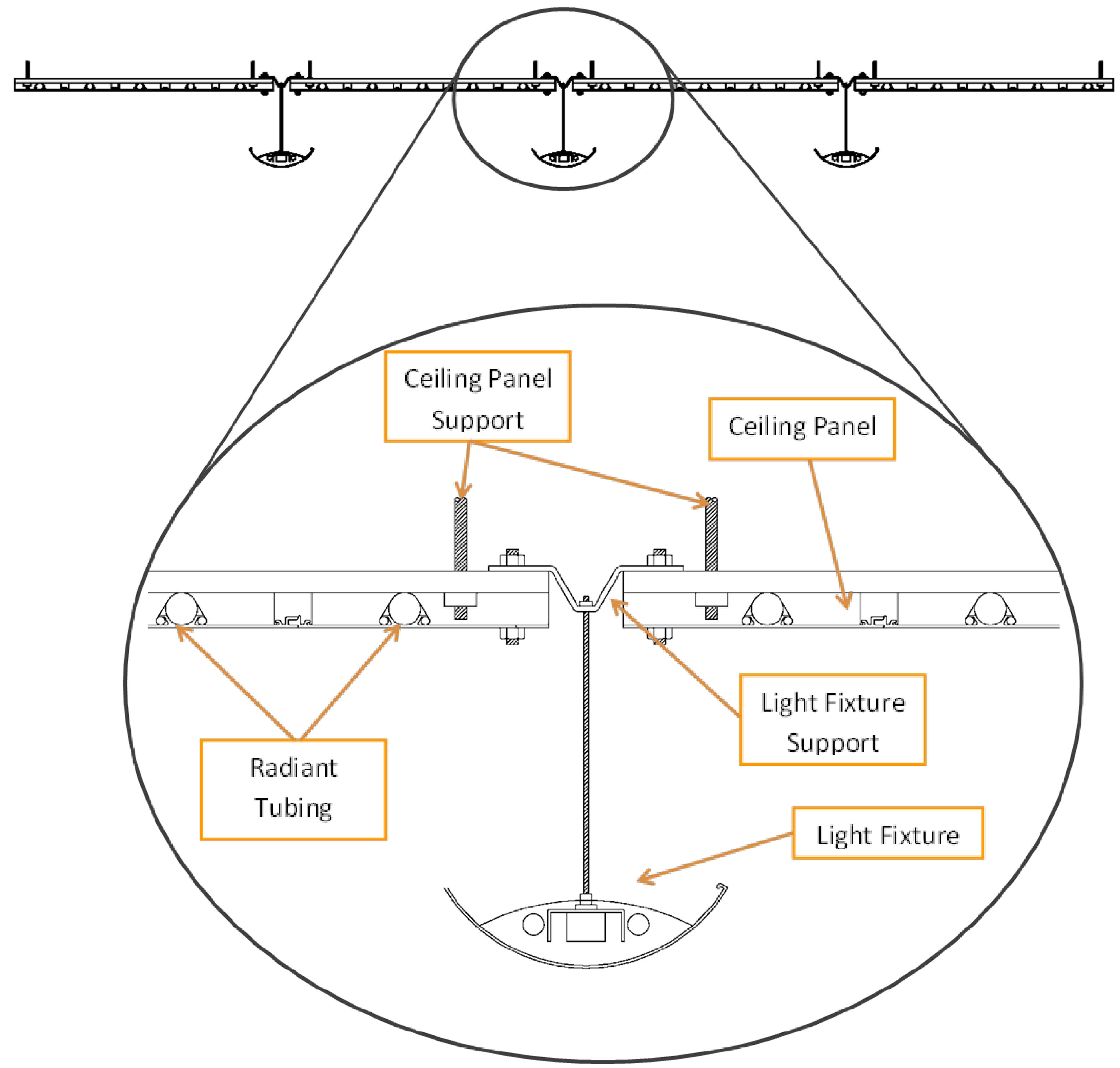
Sprinkler Piping



Room Front

Sprinkler piping will run under ceiling panels and have heads along these locations as necessary.

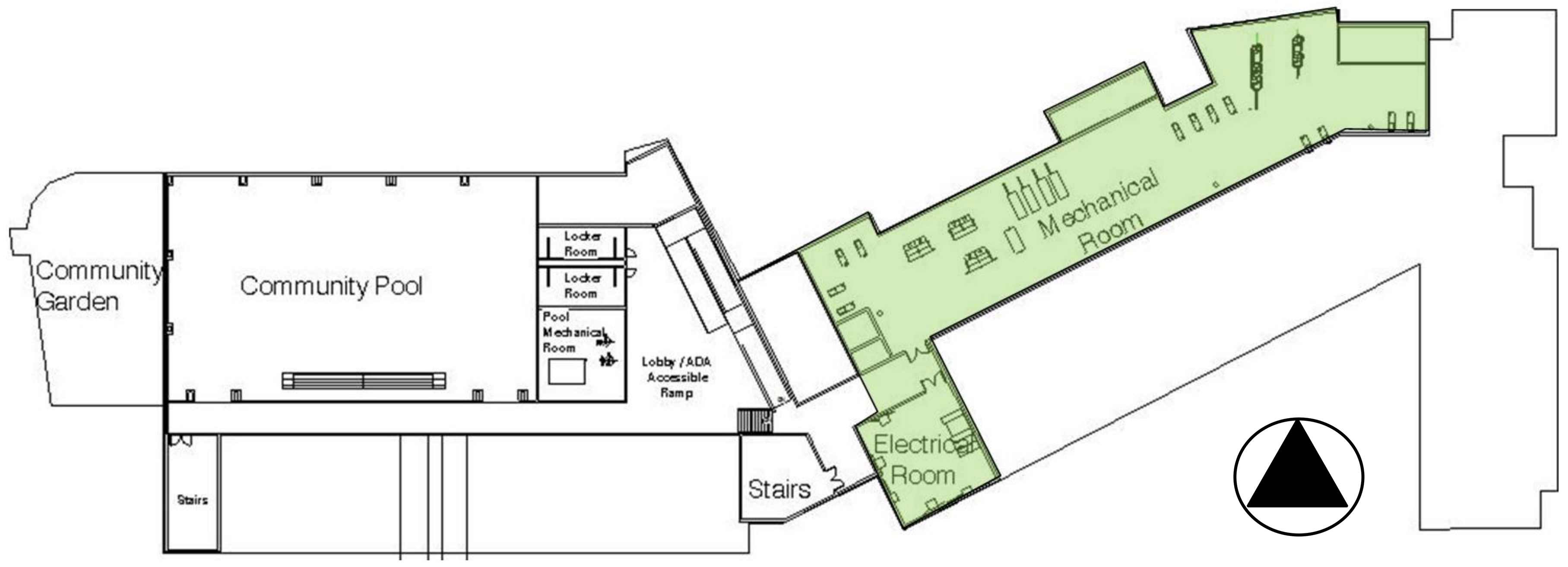
Classroom Ceiling Plans

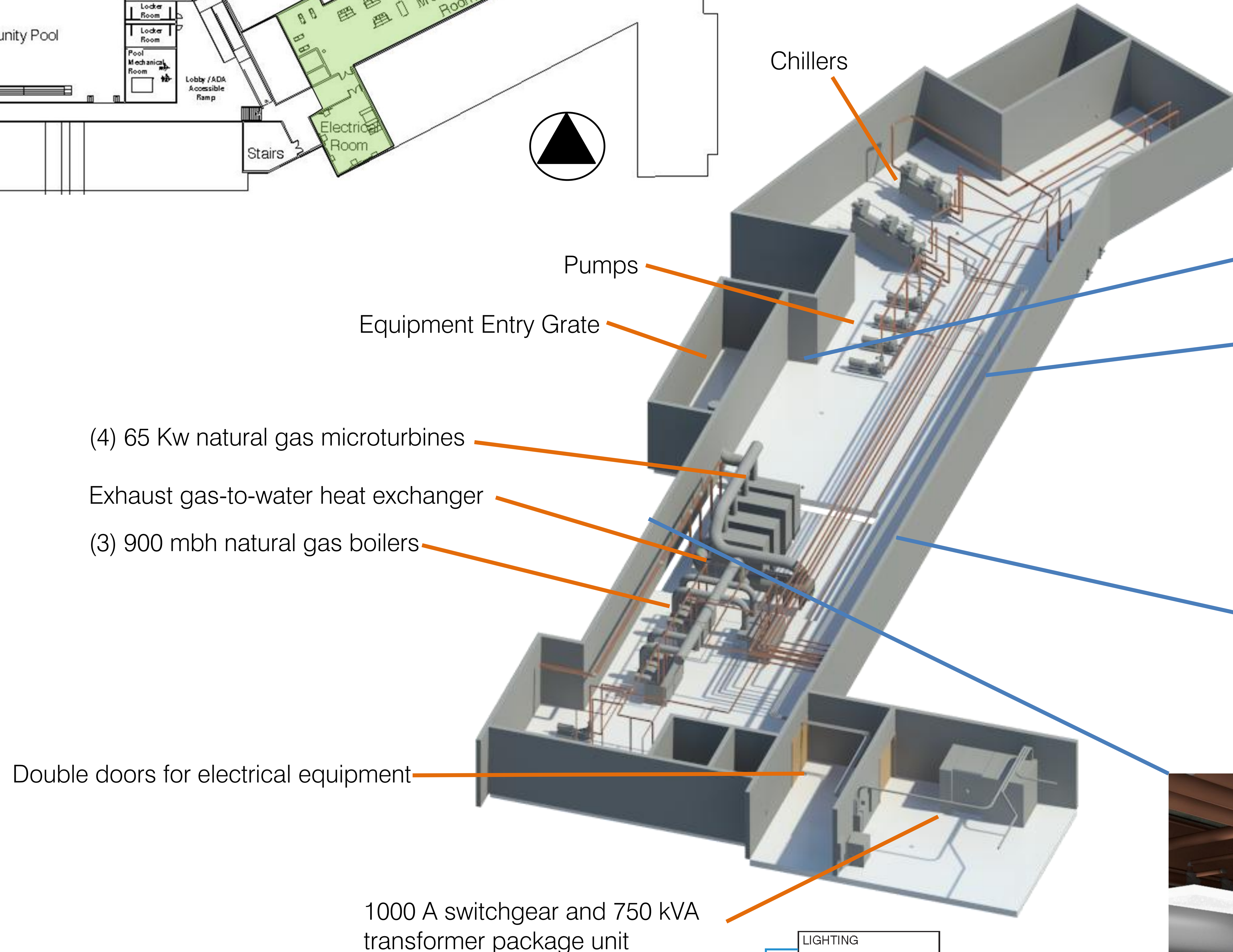


Section A-A

CM-003

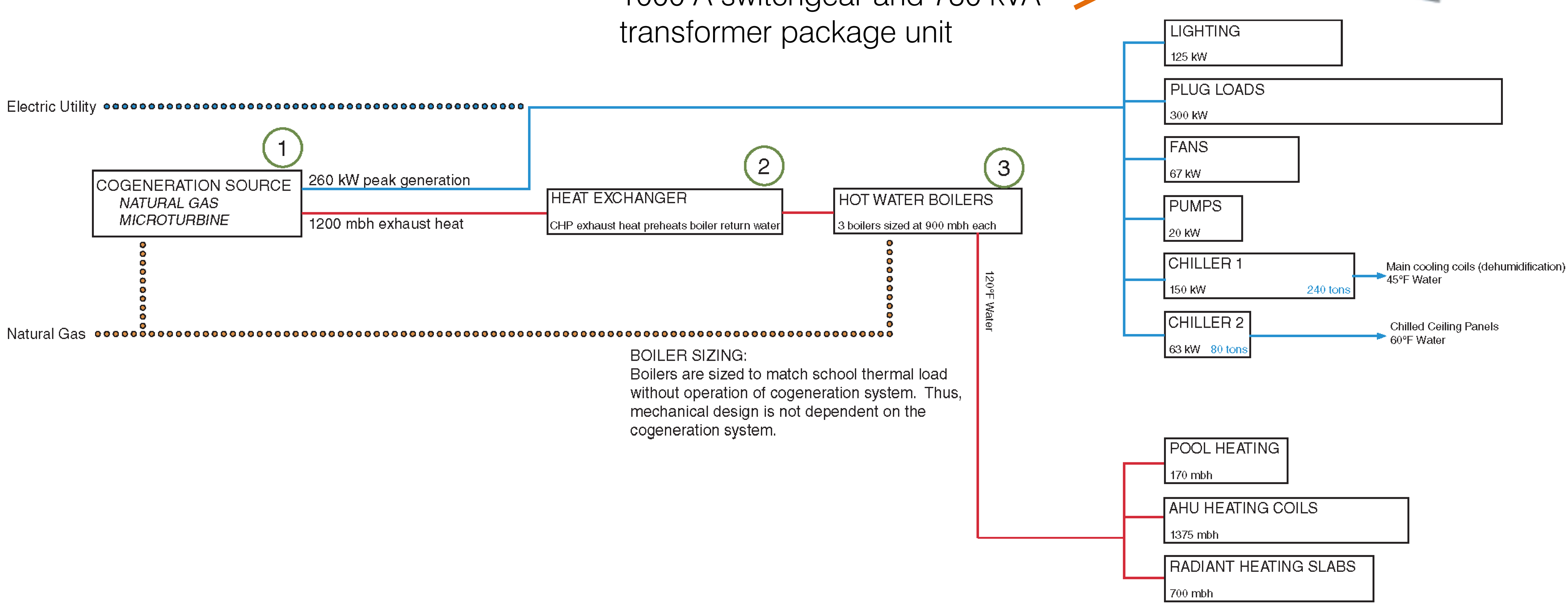
Mech. Room Coordination





Equipment Installation Sequence:

1. Switchgear/transformer
2. Boilers
3. Heat exchanger
4. Microturbines
5. Chillers
6. Pumps



CM-004

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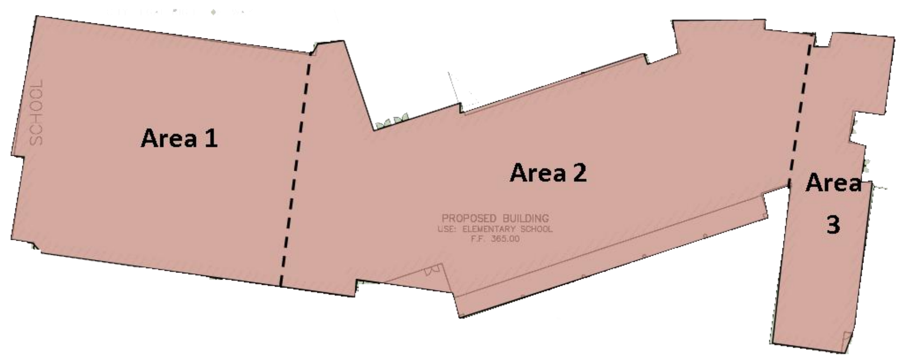
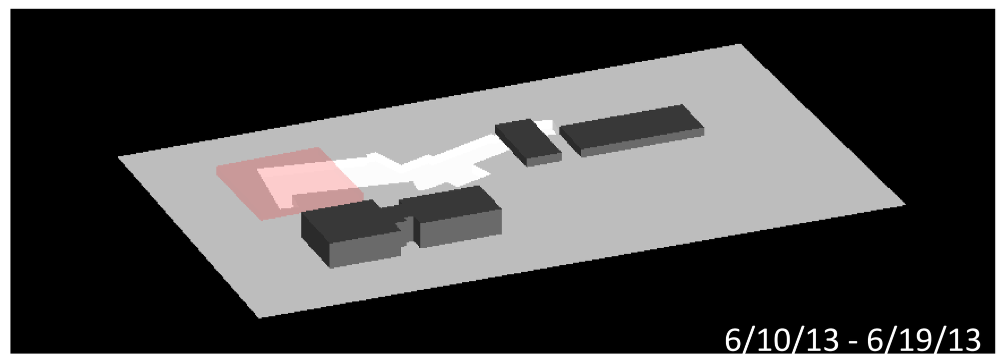
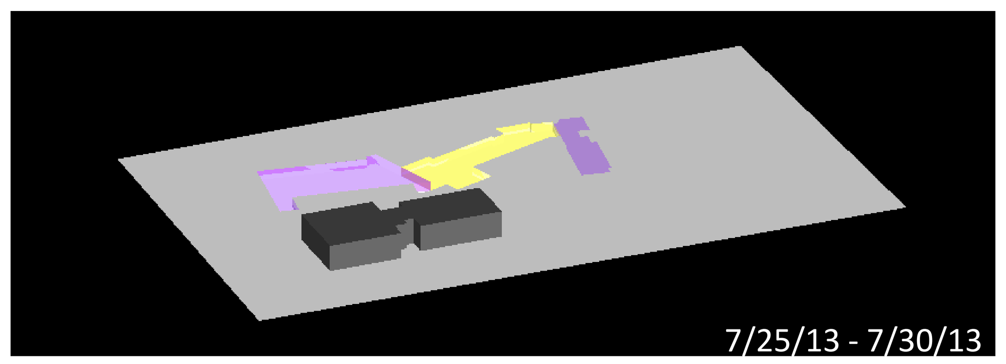
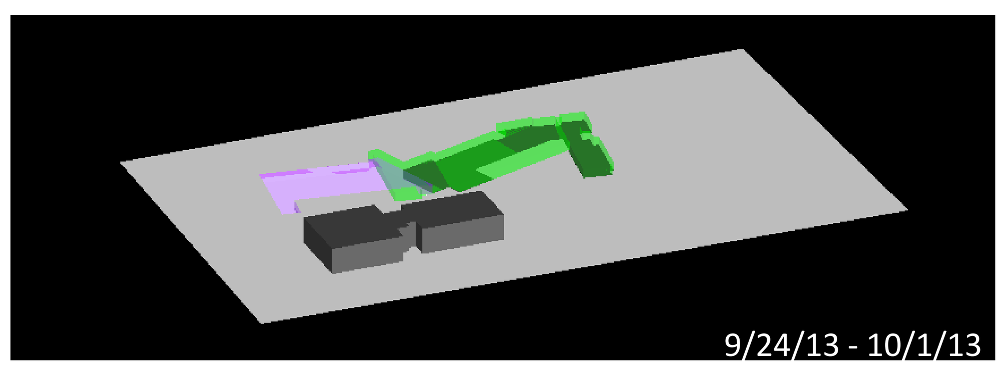
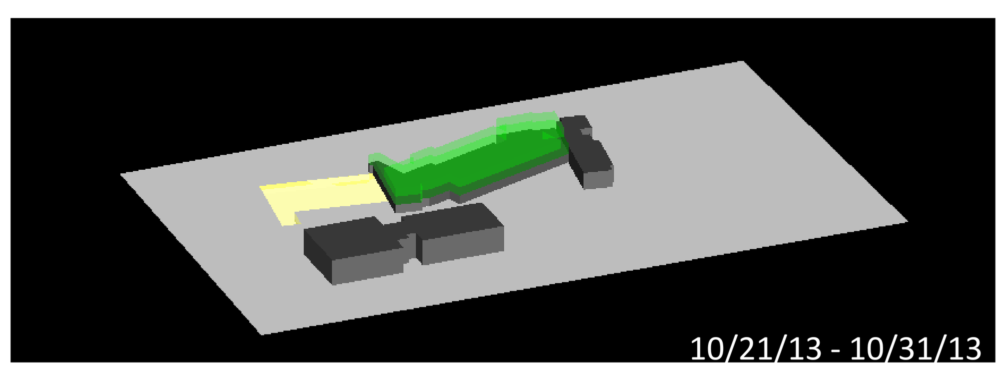
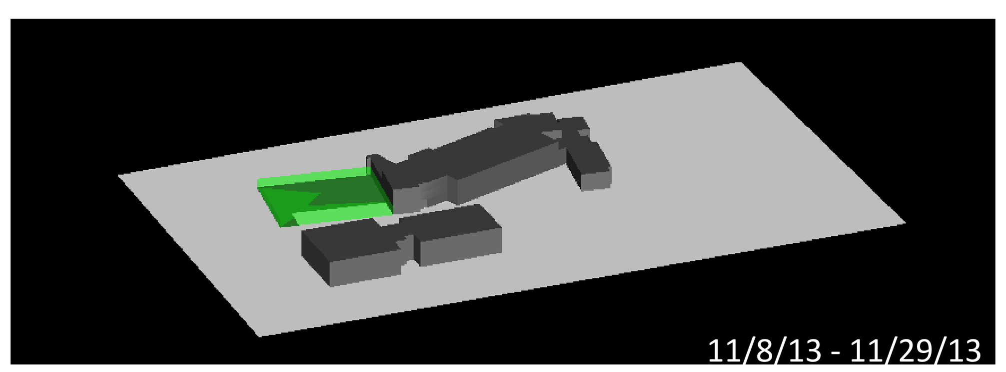
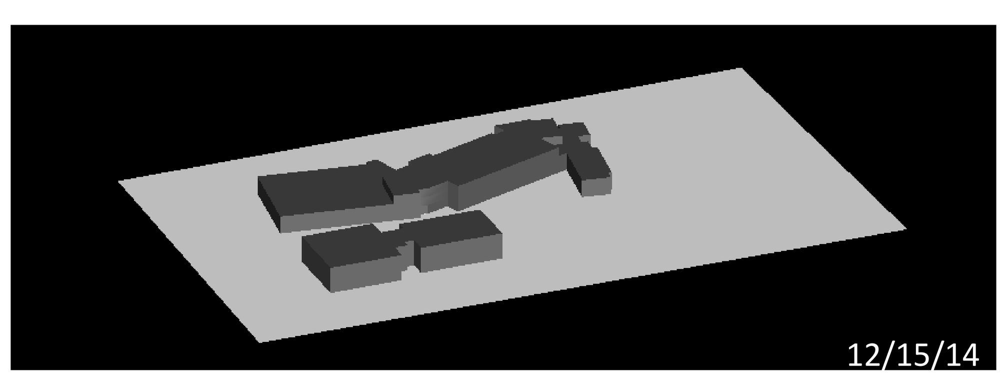
Classroom Sequencing Model



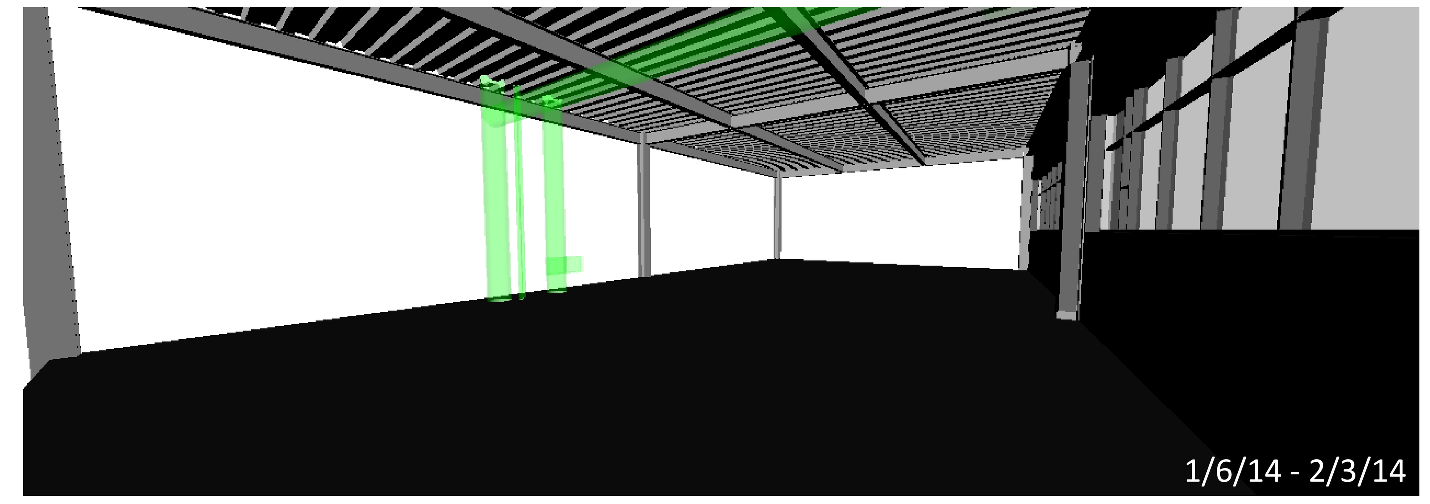
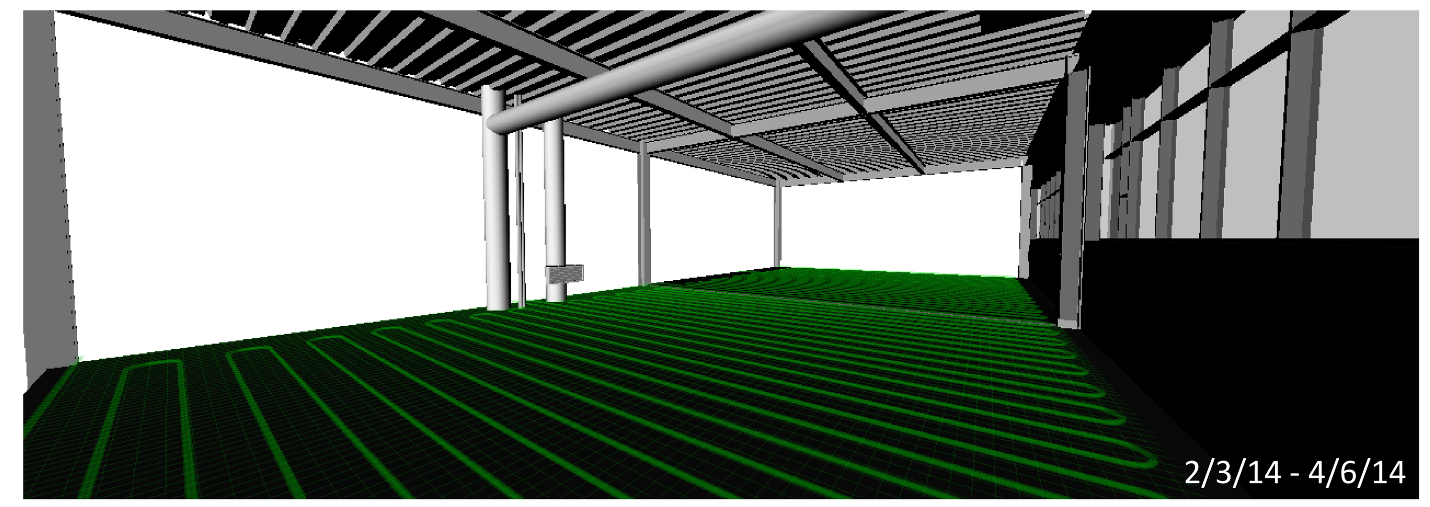
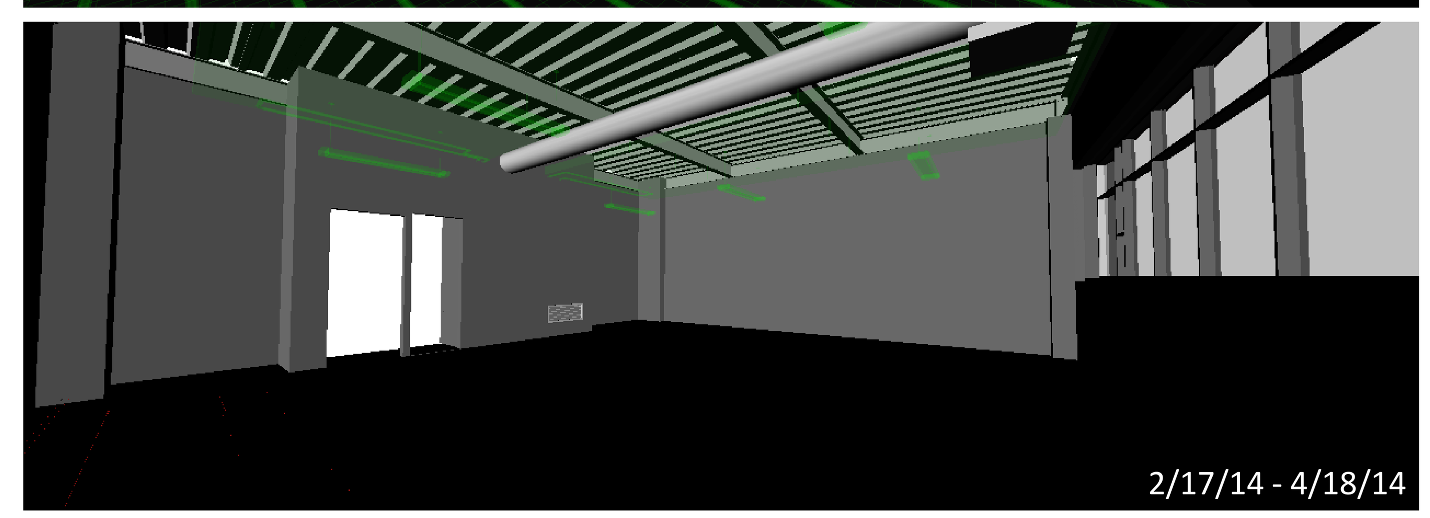
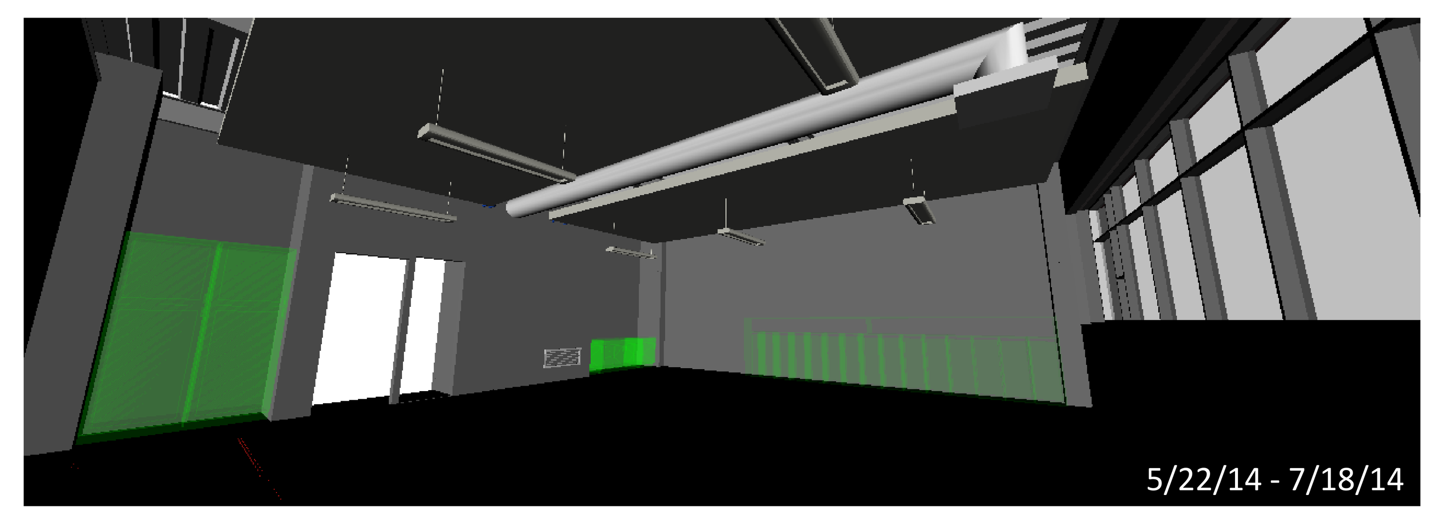
The following images are taken from the overall phasing 4D model. The colors designate the different work being completed on the project.

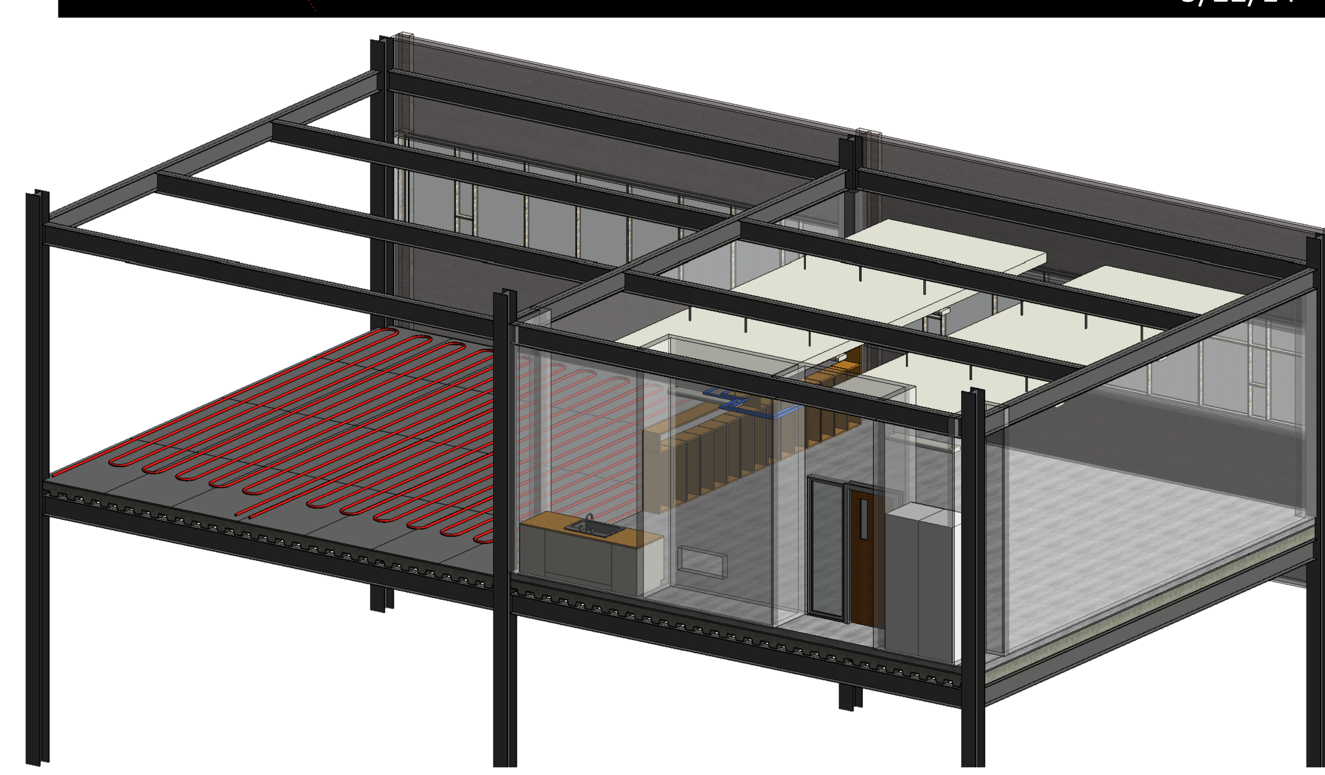
- Red – Demolition
- Purple – Excavation
- Yellow – Foundations
- Green - Superstructure

4D Phase Images	Narrative
	The demolition of building 1 has started and the contractor has mobilized to site
	The excavation of Area 1 and 3 currently in progress while the basement foundation work in Area 2 is currently being installed
	The excavation of Area 1 is continuing to progress while the 1st floor superstructure in Area 2 and 3 is being installed
	The erection of Area 3 is complete while the 3rd floor superstructure in Area 2 is in progress. The Area 1 excavation has completed and the foundation work has begun
	The erection of Area 2 and 3 is complete and the Area 1 superstructure erection has commenced
	The building has been erected

Classroom 4D Model

The following images are taken from the 4D classroom model. All Items in green are being constructed at the time the image is taken

4D Phase Images	Narrative
	The building is enclosed and the mechanical and plumbing rough –in has started
	The radiant floor construction has started with the installation of the radiant tubing across the entire floor
	The radiant floor and toping slab has been completed. The ceiling panel and light fixture installation is in progress
	The final construction of this room is the casework which will be in progress at this point



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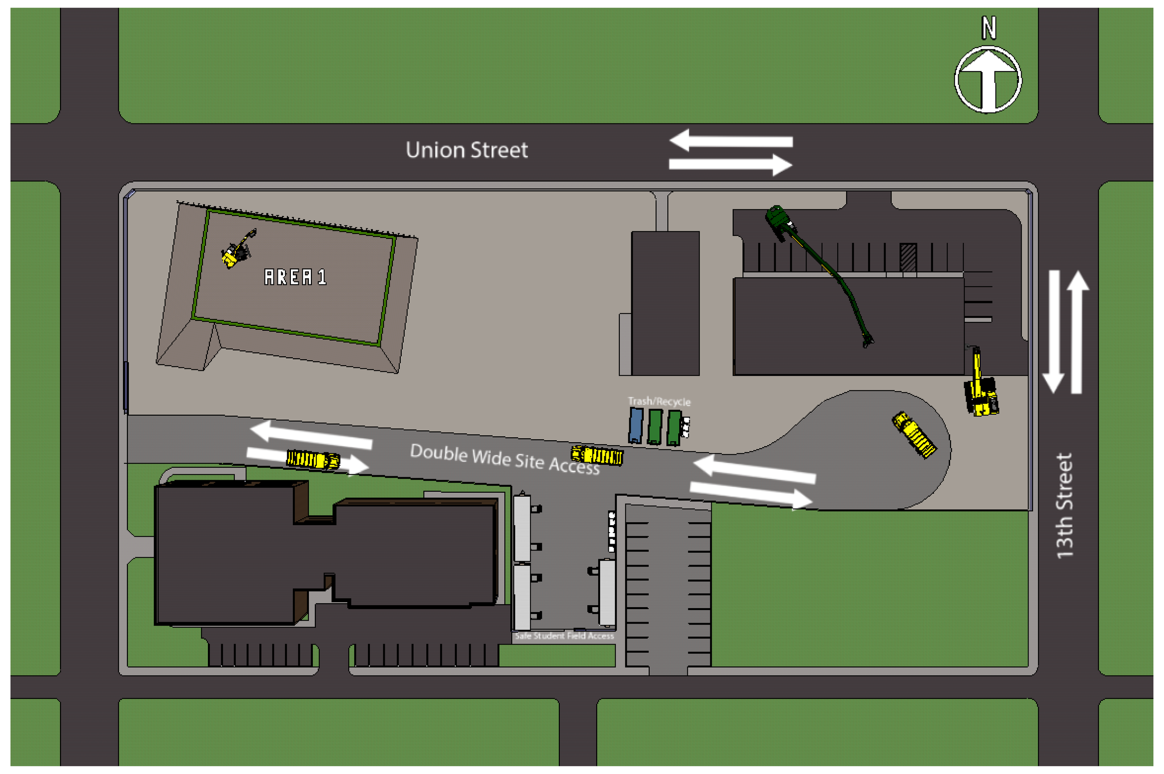
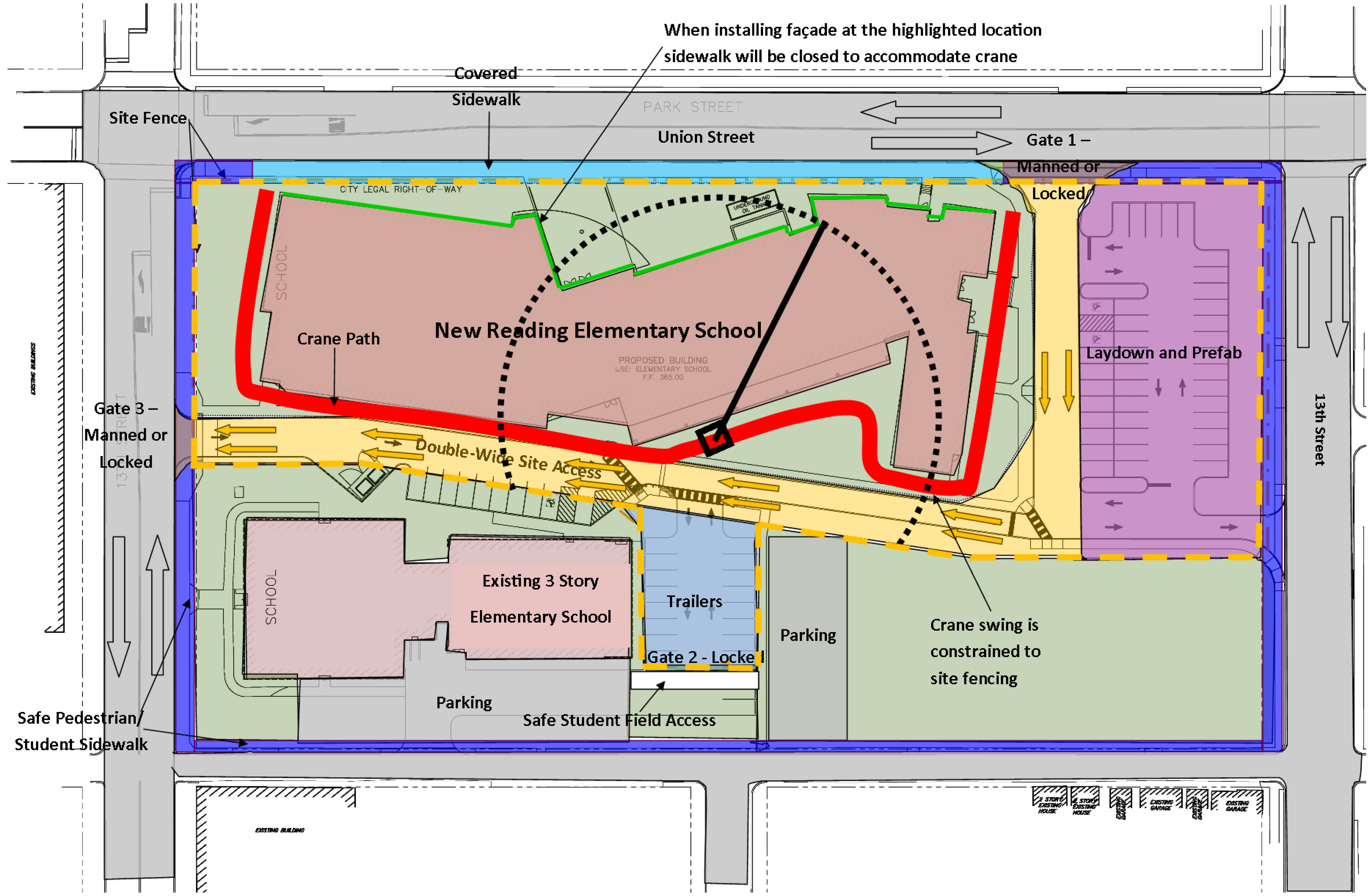
4D Models

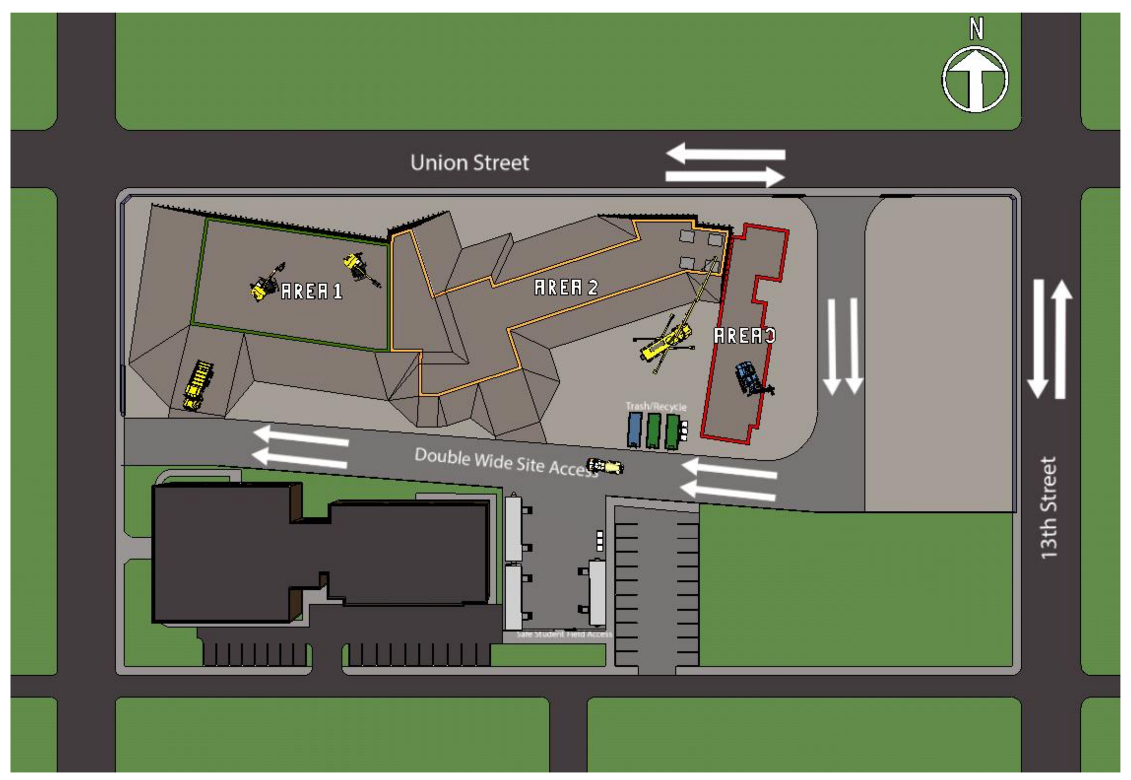


Top View Site Plan- Demolition Phase

Safety Concerns:
- Debris from demolished buildings
- Falling into excavated areas
- Demolition equipment
- Student safety as the school year ends
- Possible asbestos, remediation

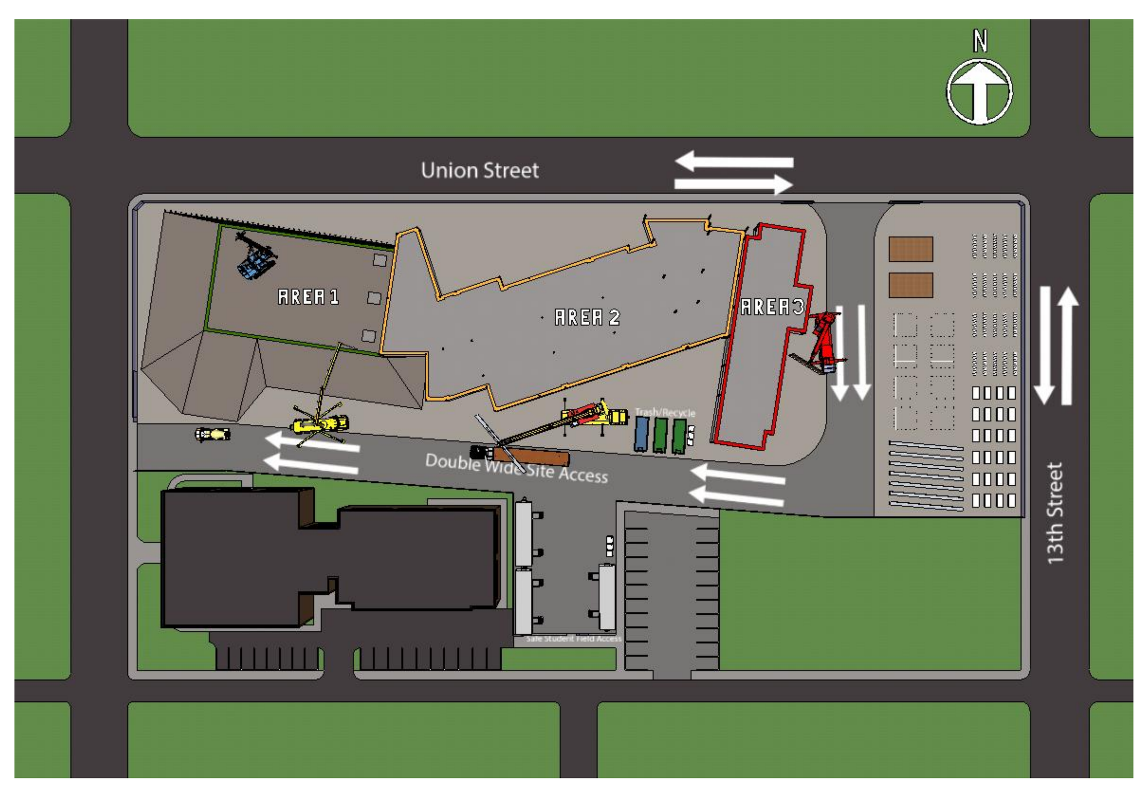


Site Safety Plan



Top View Site Plan- Foundations Phase

Safety Concerns:
- Falling into excavated areas
- Equipment blind spots
- Falling debris
- Sinkhole risks



Top View Site Plan- Steel Phase

Safety Concerns:
- Student safety during steel erection
- Falling from structure
- Crane picks
- Falling into excavated areas

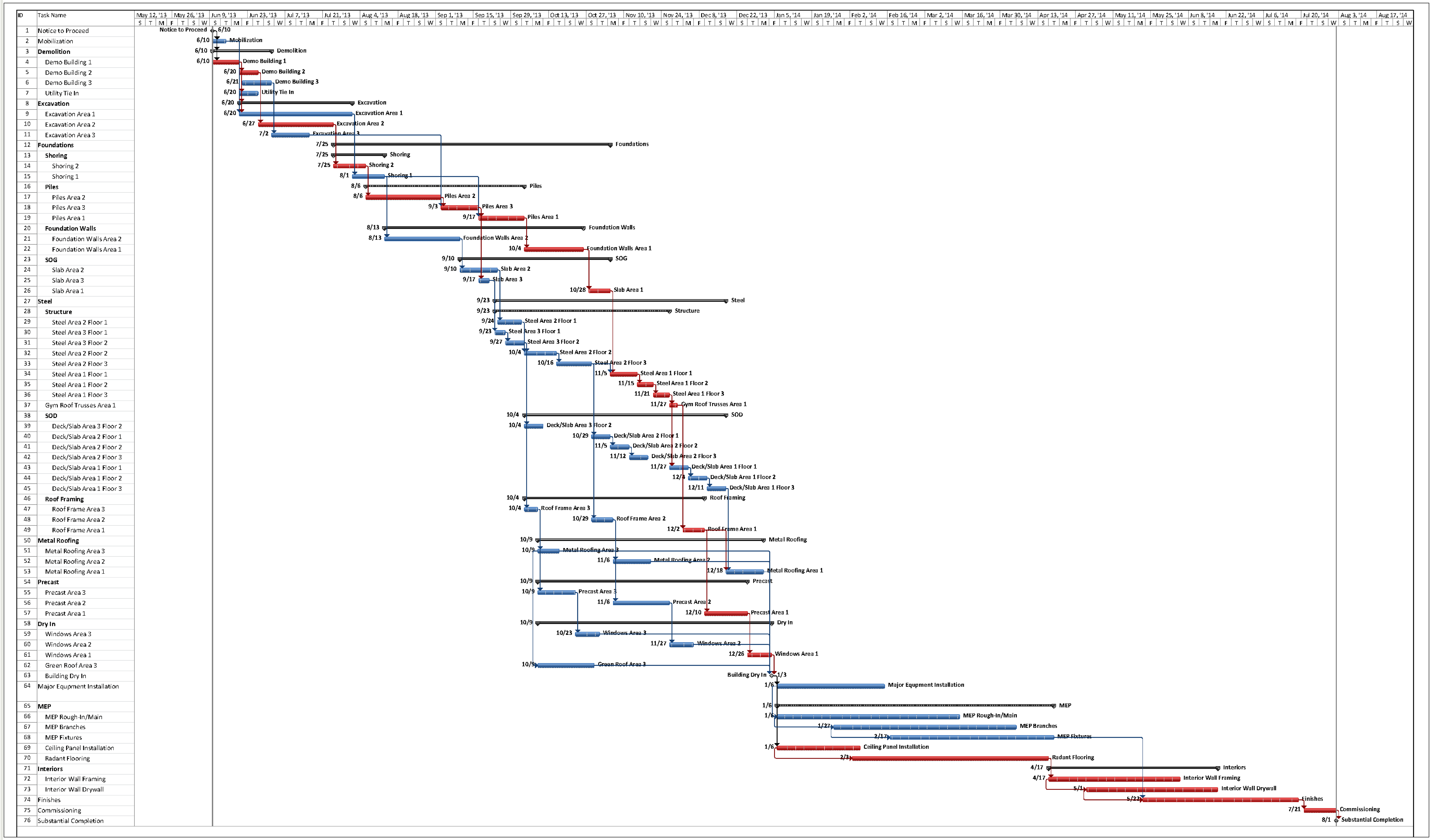
Site Safety Plan

CM-006

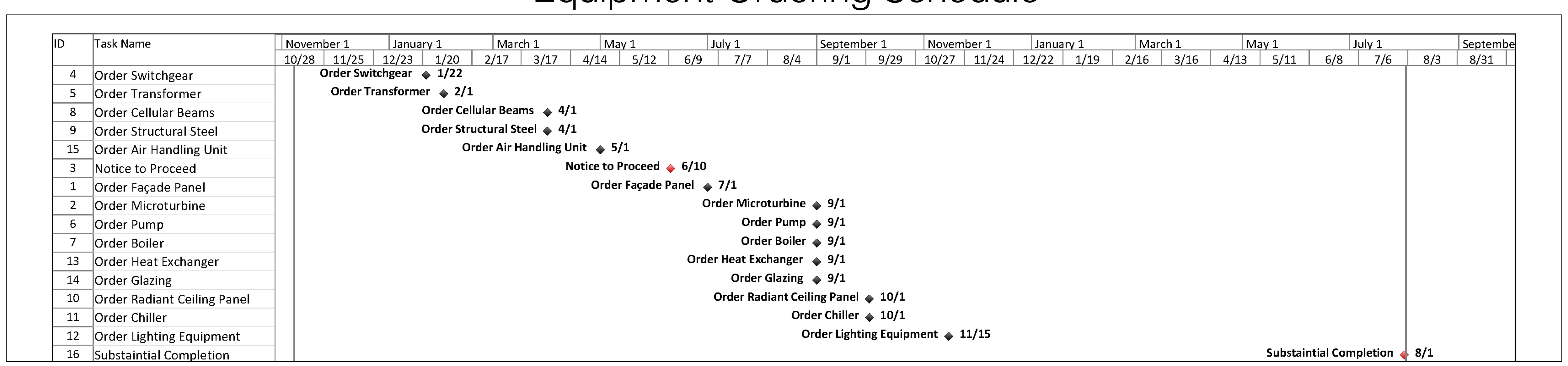
Team Registration Number 05-2013

ASCE Charles Pankow Foundation Student Competition

Construction Schedule



Equipment Ordering Schedule



CM-007

Team Registration Number 05-2013

ASCE Charles Pankow Foundation Student Competition

Schedules