Reading
Elementary
School

AEI Team 10-2013

Integration

February 22, 2013

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SECTION 1: INTEGRATION NARRATIVE

Executive Summary

Education has rapidly evolved over the past several decades. The increased complexity placed on our existing educational facilities has created the demand to rethink elementary school design. Traditional elementary school design fails our students and communities in many ways by offering inflexible spaces that limit curriculum and student creativity. The Charles Pankow Foundation Annual Architectural Engineering Student Design Competition reflects the need to rethink what an elementary school can be. The project specifically challenges our design team to improve the performance of building design through advancing integration, collaboration, communication, and efficiency. These goals were met by our design team through creative design assisted by the use of BIM technologies in accordance with our BIM execution plan. The final goal, as seen in Figure 1, is a fully-functional building information model.

Our interdisciplinary design team included members specializing in the design of structural, mechanical, lighting/electrical, and construction management. This combination creates an opportunity to analyze the professional relationships that must exist in order to create a truly integrated design and meet project goals. Specifically, the project challenges our design team to create a high performance building, to achieve a LEED certification, and to provide a realistic budget for the school district. Along with those goals our design team focused on strengthening a troubled community. Unfortunately, only 65% of Reading, Pennsylvania's population has a high school diploma compared to the overall United States rate of 86%.(1) Furthermore, Reading has a poverty rate of 37%.(1) Our team accepted this challenge understanding that this was not only a chance to improve student performance but also an opportunity to strengthen a community.

Before the design process began, our team created a BIM execution plan focusing on work flows in an attempt to reduce lead/lag time between disciplines. As an interdisciplinary team, information was requested in a timely manner so that accurate analysis could be performed. Our team benefitted from weekly design meetings and an open studio layout. The majority of our time was spent together analyzing each challenge and determining what was best for the project.

Ultimately, our design team focused on creating flexible learning spaces that can be used outside of traditional school hours for evening events and continued education programs. The exposed systems coupled with interactive monitors remind occupants of engineered systems traditionally hidden by architecture. This emphasis on exposed systems will help the occupants better understand their carbon footprint in an effort towards a more sustainable future. Additionally, our team designed an indoor pool that can be used for after-school activities and evening recreation year round to give the community a gathering spot. This is a place where Reading's population can gather and alleviate the stresses of everyday life and offer them a higher standard of living.

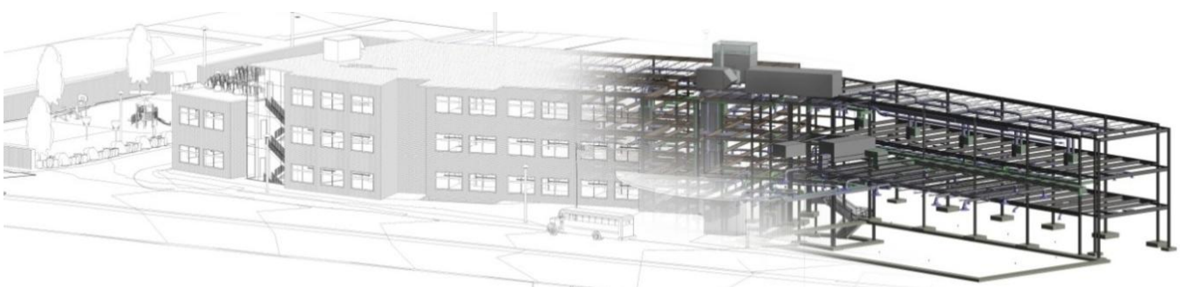


Figure 1: Building Information Model

Through the use of BIM and collaborative design techniques, our design promotes a more enjoyable, effective learning environment for students and offers a gathering spot for community events. The design will offer a safe and effective learning environment built for the future and reduce peer pressure and temptations in young adults through after-school activities and continued education programs. This renewal in Reading's education and community will lead to higher high school diploma rates and college acceptance. Without the assistance of BIM technologies and an integrated approach, project goals would be difficult to achieve. Our team successfully achieved the project goals listed above.

Summary of Building Systems

Through the use of BIM and collaborative design techniques, our team has designed and implemented integrated engineering systems which promote a more enjoyable, effective learning environment for students. This learning environment will contribute to achieving goals of increased student attendance, test scores, and teacher satisfaction. It cannot be emphasized enough that our team envisions the proposed elementary school as not only a high-performance building, but also as a positive landmark and influence on the surrounding community. A summary of the building systems which helped us achieve this goal can be seen in Table 1.

Table 1: Summary of Building Systems

Structural	Geopier foundation system; composite steel framing with hybrid masonry walls; multi-hazard resistant multipurpose shelter
Mechanical	Hybrid system utilizing ground coupled heat pumps to offset traditional heating/cooling
Lighting	Daylight as a primary light souce combined with electric light to enhance overall aesthetics and energy efficiency while improving learning environment
Electrical	Organized power distribution to monitor building usage and provide a safe and secure learning environment
Construction	Design build delivery method with a guaranteed maximum price; 16-month construction duration
Architectural	Community pool included at basement level of proposed school; green roof outdoor learning environment; community playground on east portion of project site; precast-panel façade system combined with exterior glazing for optimum daylighting efficiency; comprehensive security plan; elimination of cantilever at south wall for a more uniform building facade

Site Layout and Modifications

Certain aspects of the proposed elementary school and the site layout are unique to our design. These unique features along with other important parts of the school are annotated in Figure 2.

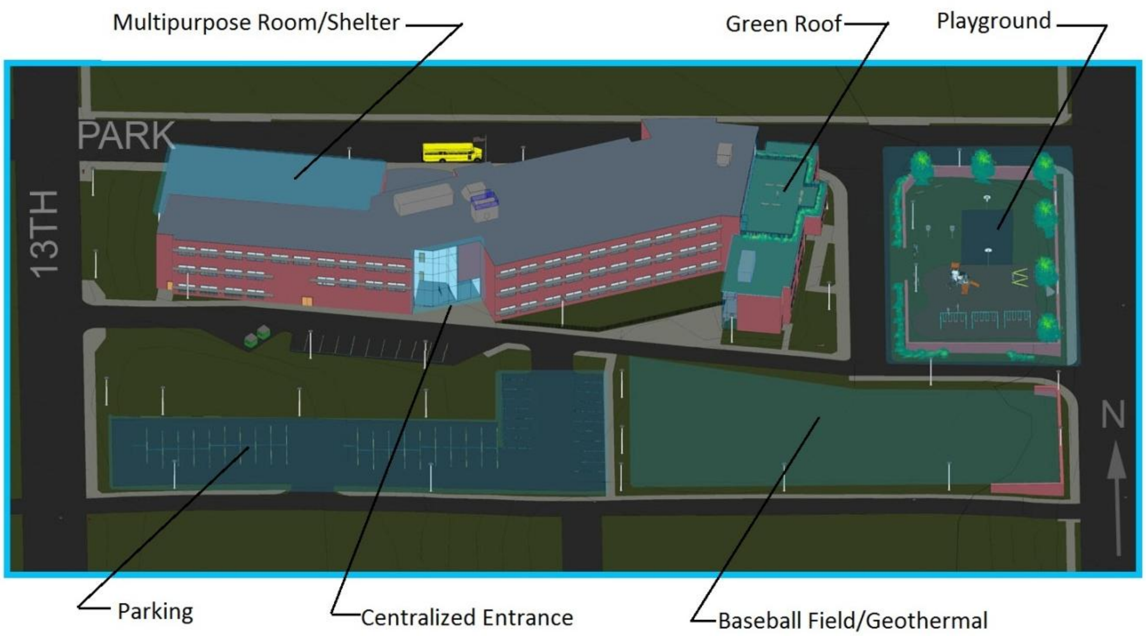


Figure 2: Bird's-Eye View Showing Proposed Elementary School Site

The most significant site changes that our team made regarding the site was demolishing the existing school to relocate parking lots and use the area originally designed for parking to build a community playground for the city of Reading. It should be noted that materials from the demolished existing school will be recycled as appropriate.

Including a playground in the design was presented as an option in the competition program, but our team saw this as an incredible opportunity to benefit the surrounding community. Our original idea was to locate the playground at the southwest corner of the site, in place of the demolished existing school. However, once we began looking at possible scheduling ideas, we realized that it would be more beneficial to pave over this area rather than do extensive site work and build a playground. This was a concern because demolition and new construction must be completed during the summer while school is not in session. Cost and security concerns also supported relocating the playgrounds.

From a cost standpoint, it will be more cost effective and resourceful to utilize some of the existing parking spaces that are currently in use at the existing school. This means we will be adding parking lot spaces to the existing lot rather than constructing completely new parking lots. Also, from a security standpoint, we understand that the school will be utilized for after-school activities. Having parking lots centrally located will help optimize the efficiency of our security plan. Our main concern was that people attending after-school functions would need to travel the length of the building to reach the multipurpose room. By entering in the middle zone of the school, we hope to utilize the space as a central security hub that will restrict access to parts of the school. Also, during school hours, visitors will be able to enter through the center doors and check-in with administration.

Another unique site change is the addition of a concrete barrier wall around the playground and the existing baseball field (the primary areas where children will be present on site). The primary function of this wall is to ensure security and safety by keeping intruders outside and children inside these areas. These strong concrete walls, discussed further in the Security section, also prevent nearby vehicles from endangering the children in the event of a car accident.

Other areas worth noting are the green roof on the east wing of the school and the multipurpose area, which has been designed as a community shelter in coordination with the local Homeland Security department as mentioned in the competition program. Not visible in Figure 2 is the community pool, which has been added to the design at the basement level of the proposed elementary school. All of these areas are discussed in much further detail later in this report.

Building Envelope

Ideally, the facility enclosure is designed to optimize energy efficiency while also delivering an aesthetically pleasing architectural façade. The building envelope was a major area of collaboration, and this is evident in the envelope our team has provided for the elementary school. Our design addresses daylighting, solar heat gain, structural considerations, and constructability as pertaining to all four disciplines present on our team.

Façade

When researching different façade types and systems, our team looked for a façade system that provided benefits to the owner. We came across precast panel systems, and our design team strongly recommends the SlenderWall precast panel façade system.[2] This particular system not only provides extensive benefits structurally and thermally, but it also enhances constructability. The panelized approach also allows for easier glazing placement from a daylighting standpoint. An isometric section of the school's façade, as modeled in Revit, can be seen in Figure 3. Advantages of this particular precast panel façade system are summarized below but are also discussed further in each individual discipline report.

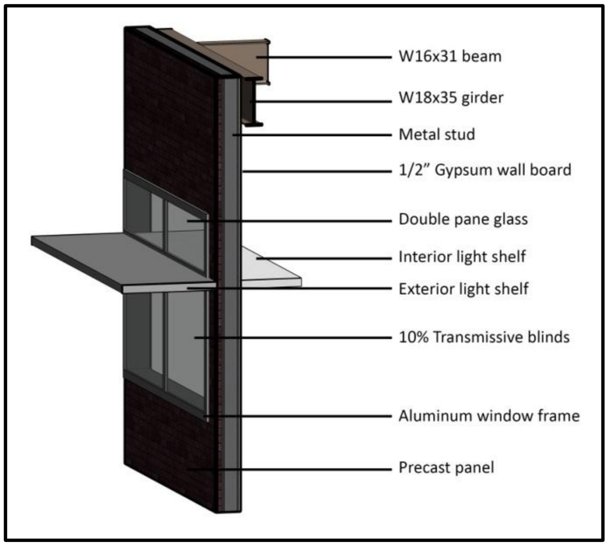


Figure 3: Integrated Façade Section from Revit

Structurally, the SlenderWall system provides a lightweight façade option at only 30 pounds per square foot.[2] It should also be noted that the façade system is not loadbearing, as metal studs carry the self-weight to spandrel beams.[2] Structural logistics are further discussed in the Structural Systems Report.

Mechanically and thermally speaking, this façade construction has the potential to reduce thermal transfer from exterior to interior by 25%.[2] Also, the R-value of this system is R-21, which is above the ASHRAE 90.1 minimum of R-13 for climate zone 5A.[2,3]

The building façade selection was also impacted by constructability analysis. When analyzing SlenderWall's constructability, there were many aspects that we favored over traditional methods. Some of the advantages of any precast wall over a site-built wall are schedule, quality control, safety, aesthetics, and in the case of our particular system, cost as discussed below. Considering these features coupled with the investigations of all other design team members, this system was found to be the most effective method of exterior façade construction. For typical construction details and sections of the precast façade system, please refer to Appendix D.

By using a precast wall panel, a significant aspect of the wall construction schedule can be controlled simply based on panel erection time. Weather and interdisciplinary delays will have limited effects on the project schedule. Quality control is another favorable aspect of precast architectural panels. These panels can be prefabricated and shipped on site on a flatbed truck. By constructing panels in a controlled shop environment, overall quality can be greatly increased. This also eliminates some of the risks involved with field construction.

Our design team performed a cost analysis of the SlenderWall façade system. We found the total cost of the façade system as $1,307,574 compared to an expected R.S. Means value of $1,474,000 for a typical façade system on an elementary school of similar size and location.[4] More detailed cost comparisons are presented in the Construction Report. Overall, the selection of this precast panel façade system fits our design goals and alleviates potential constructability concerns.

Daylight

Daylight in the facility saves electrical lighting energy and enhances interior aesthetics. Glazing locations optimize energy savings by limiting west oriented glazing apertures. By limiting west-facing windows, peak mechanical and electrical loads are reduced. Reducing electricity consumption during peak loading hours avoids increased demand charges from electrical utilities in the afternoon. Reducing peak mechanical loads that often occur in the afternoon after solar radiation is absorbed and re-radiated into the building allows mechanical equipment sizes to be reduced. Typical window heat gain and daylight autonomy for a classroom with shades up can be seen in Figure 4.

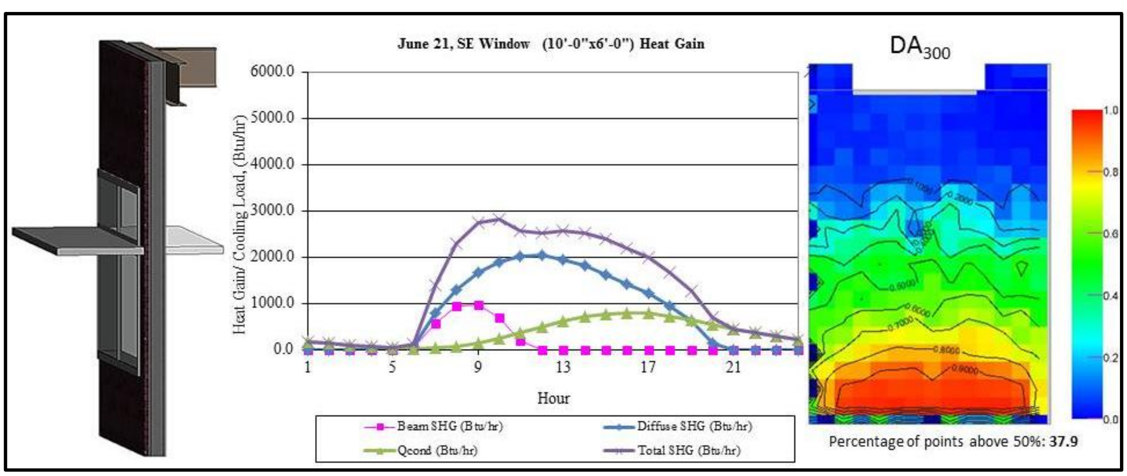


Figure 4: Southeast-Facing Exterior and Interior Light Shelf Window Performance

The building envelope purposely provides large amounts of exterior glazing on south and southeast oriented façades. Refer to Appendix D for illuminance levels in a typical classroom. The south and southeast façades are controlled with exterior light shelves to reduce direct solar radiation at high solar altitude angles, while allowing passive solar heating at low altitude angles in the winter. Exterior light shelf effectiveness at improving occupant comfort and reducing energy consumption warrants the additional cost.

Unique Collaboration Areas

It is important to note that our design team collaborated with individual engineering systems throughout the entire elementary school. However, there were unique areas throughout the elementary school which our design team would like to emphasize, as can be seen in the following discussions.

Classroom

One of the main driving forces behind our classroom design was using the building itself as a learning tool. We applied this concept by exposing the structural framing and ducts in classrooms to emphasize how building systems work and fit together in a collaborative manner. Building systems will be color-coded to make them more visible and easily understood. In high traffic areas, monitors will display building energy performance, and these interactive displays will highlight the facilities energy demand and encourage occupants to conserve energy when possible. The designs needed to be carefully orchestrated to come together and act as architectural features. Our design team created a 3D mockup of a typical classroom in Revit to ensure there were no integration issues. This 3D image can be seen in Figure 5.

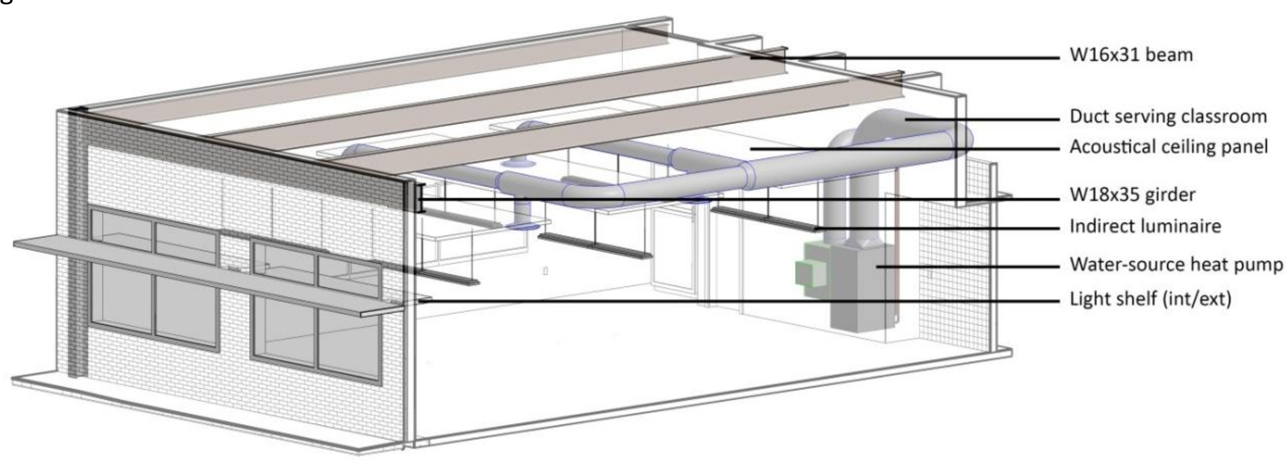


Figure 5: Classroom Systems Integration

Corridor

Similar to the classroom, the corridor was also a unique area of collaboration due to the simple fact of special limitations. Because main duct runs, cable trays and piping also needed to be accommodated in the corridor ceiling plenum with the steel framing, luminaires and electrical conduit, our team spent a great deal of time laying out and modeling these engineering systems to ensure no clashes occurred. A 3D image of the clash-free corridor space can be seen in Figure 6.

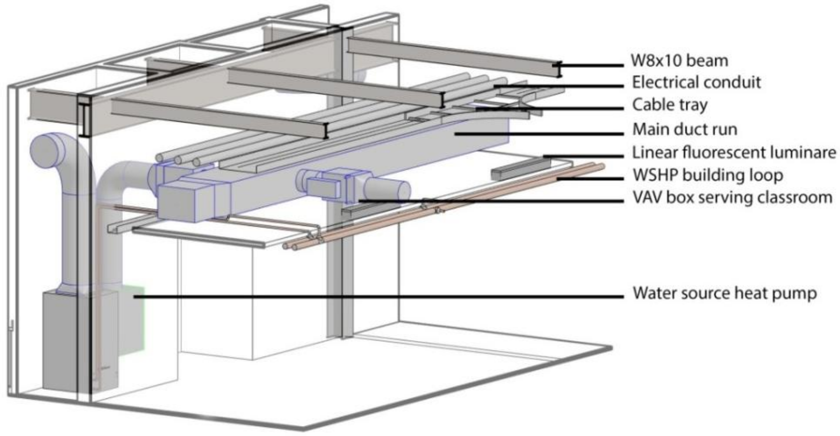


Figure 6: Corridor Systems Integration

Shelter/Multipurpose Area

The competition program mentions the idea of using the school as a shelter facility as part of the local Homeland Security department. In order to shelter as many community occupants as possible, our team decided that the multipurpose area will be used as a shelter facility, as previously seen in Figure 2. We designed this section of the facility to be a safe haven in the event of severe weather or other emergency situations. Our shelter was designed in accordance with FEMA 453 (Design Guidance for Shelters and Safe Rooms), and Unified Facilities Criteria (UFC) 4-023-07 was used to evaluate our shelter from a ballistics standpoint to protect occupants from drive-by shootings or any other possible external attacks.[5,6] The importance of this space was emphasized throughout the design process, and we considered as many potential hazards as possible to maximize safety of the facility.

Shelter Criteria and Design

For the shelter to be completely safe from the external environment, we decided to design the area as a completely separate structure. The school will be directly against the shelter facility and will look to be part of the same building from the outside. This separation allowed our structural team to keep the elementary school as Risk Category III while only moving the multipurpose area up to Risk Category IV per ASCE 7-10.[7] The elevated Risk Category requires the design of the shelter to be more rigorous, which is exactly what we were aiming for with the design.

In the interest of the shelter being a separate facility, we also designed our mechanical and electrical systems to be separate from the rest of the school. Generators will provide a backup power source in the case of an emergency scenario. All power loads that will be on emergency power will have to be transferred to an electrical panel which will be serviced by normal utility power in addition to emergency power. These panels will be equipped with automatic transfer switches to transfer the source of power from utility to the generators upon a loss in utility power. Not only is emergency power necessary for equipment such as air handlers and lights, but it is also essential for people with ventilators, suctioning devices, and other life-sustaining equipment.[8]

Eight-inch fully-grouted reinforced concrete masonry walls with pilasters spaced at 8 feet on center will provide the walls with enough stiffness to withstand the hurricane force winds that could be expected in an extreme weather event. Through structural analysis software, it was determined that the walls are capable of withstanding pressures induced from winds in excess of 135 mph. Not only does fully-grouting the masonry help to handle the forces induced by wind loading, but it also mitigates the risk of perforations from airborne debris in the case of extreme high winds or ballistic penetration as discussed below.

The roof above the multipurpose area will be a specially designed system capable of withstanding extreme uplift pressures caused by winds of up to 120 mph. We specified the Sika Sarnafil Engineered Roof System or an approved equivalent due to its specialized design to withstand uplift forces. Per the specifications, this system exceeds Factory Mutual requirements for wind uplift testing.(9) This system is discussed in more detail in the Structural Systems Report.

Another situation of concern that was considered was protection from ballistic attacks. Using UFC 4-023-07, we found that if we grouted all cores in our 8” masonry walls, we would qualify to protect against a design basis threat of “High”. This threat level includes ANSI/UL 752 Level 9 (.30 caliber Armor Piercing) at 800 meters.

Engineering and Collaboration

The multipurpose area, like the community pool, was also an area of very high collaboration when designing and laying out the engineering systems within. Our structural, construction management, mechanical, and lighting/electrical members all worked together to develop a logical layout of the engineering systems under the roof to ensure no clashes or discrepancies were present. By modeling our systems in Revit and collaborating through the entire design process on various aspects such as duct size, lighting fixture length, and framing depth/spacing, our team created an architecturally-pleasing, clash-free and efficient system layout in the multipurpose area, as seen in Figure 7.

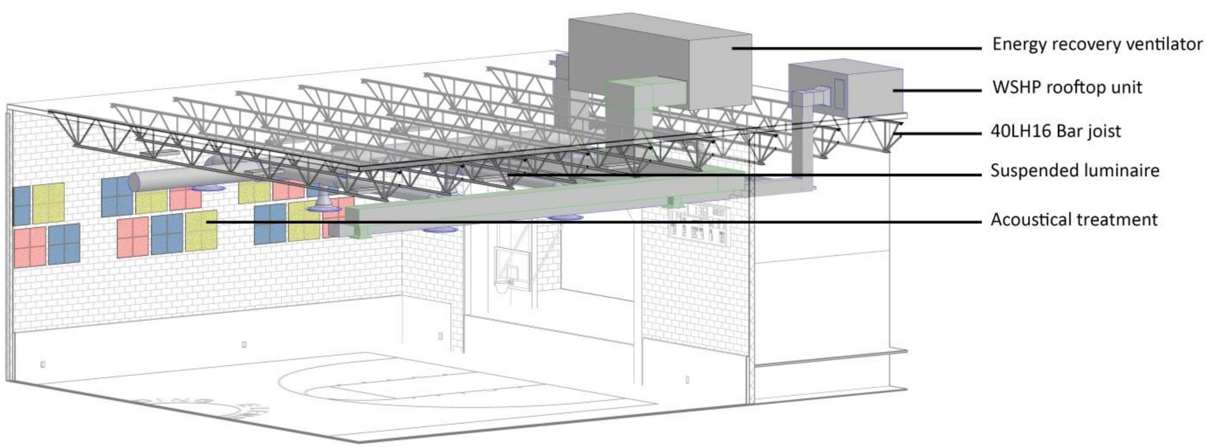


Figure 7: Multipurpose Systems Integration

Community Pool

Location

Another area of the school that saw a substantial amount of collaboration between disciplines was the community swimming pool. The pool was a unique area because a set location was not provided to our design team. Thus, the first step in the design process was selecting a location based on discipline-specific criteria and community benefit.

At first, we considered putting the pool outside, but realized that Reading's climate would not warrant an outdoor pool. It was our belief that an outdoor pool would not gain maximum use for the investment that was made. Another option was to perhaps use the location of the existing school and possibly the existing building itself to create an indoor location for the swimming pool. However, this option was unfavorable because our team had intentions to demolish the existing school and utilize the extra site area for centrally located parking lots and a community playground adjacent to the new school. It is also unlikely that the structure in the existing building would lend itself to the architectural constraints a pool creates, such as long spans and foundation capacities.

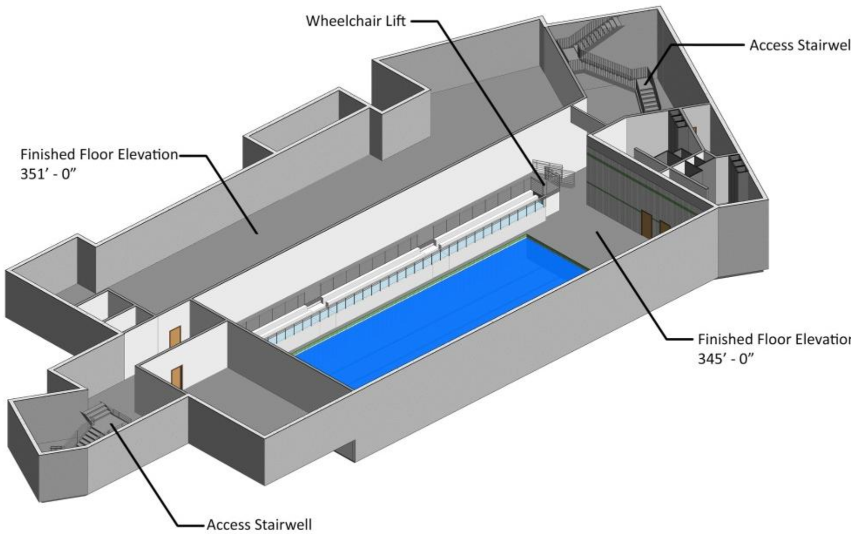


Figure 8: Basement and Pool Level Logistics

We determined that the basement level of the proposed school was the best possible location for the pool so that the school can truly act as a hub for community activities, and an isometric view of this space can be seen in Figure 8. Since all areas to be used for after-school activities (such as the community room and multipurpose area) are centrally located in our building, it makes sense for the pool to also be centrally located in this area. This will also make security easier to handle and safer because no more exterior entrances were added to the school as a result of our design. Limiting entry points allow for a more secure environment.

It is important to note that our team did consider the addition of a separate structure on site to accommodate the community pool space. However, it was determined that it would be much more cost-efficient to include the pool as part of the new elementary school rather than as a separate freestanding structure. Additional excavation, structural, mechanical, lighting, and electrical costs are greatly reduced because these systems can tie into the elementary school if the pool is located in the basement. Also, including the pool as part of the school allows greater flexibility in parking areas as well as the addition of a playground adjacent to the school.

Engineering and Collaboration

The addition of a pool in the basement meant substantial engineering and architectural collaboration was to be performed in this area. First, to ensure a comfortable floor-to-ceiling height for a competition pool space, our design team lowered the finished floor elevation of the pool space six feet (6'-0") below that of the rest of the basement, as seen in Figure 8. This also alleviated glare issues that would come with having lights suspended too close to the pool surface. Due to the open plan space required for a pool, W40X149 transfer girders were included to handle point loads from columns above which would otherwise come down in the middle of the plan. Composite open-web floor joists (40CJ32) also help frame the 1st floor above the open pool area. Framing for this area is further illustrated in our Structural Systems Report. Nevertheless, due to the increased floor-to-ceiling height, framing depth was not an issue, but collaboration needed to occur between other disciplines.

Once the framing depth and member locations were set, our mechanical team worked closely with the lighting design team to create a design that benefitted the space both mechanically and in terms of maximizing lighting efficiency. Our team modeled all systems in Revit and paid special attention to this area to ensure no clashes occurred during design. Through this collaborative effort, our design team developed a competition pool area complete with a logical and constructible engineering systems layout, as seen in Figure 9.

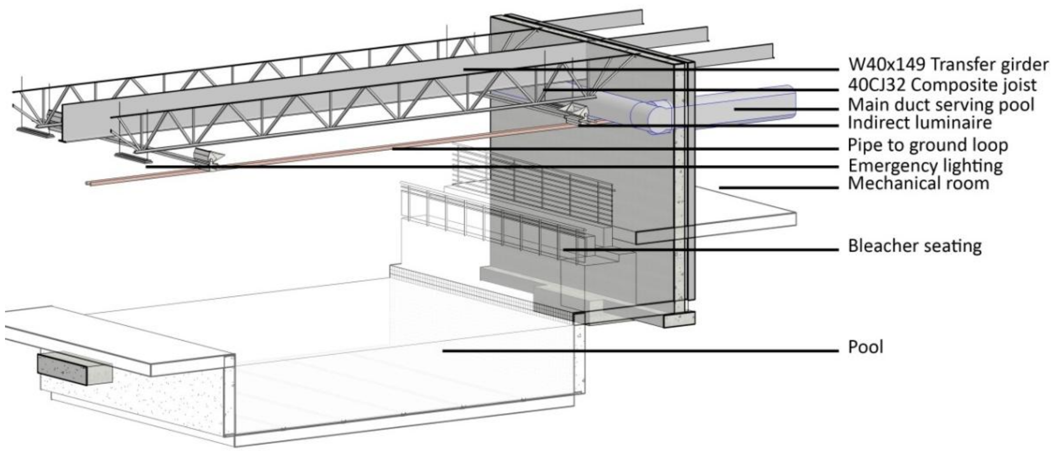


Figure 9: Community Pool Systems Integration

Additional Considerations

In our design, visitors will come down the main staircase and arrive at the top row of spectating bleachers. From this point they can utilize stairs to get down to the pool level, and for disabled individuals, a wheelchair lift will be located near the stairs leading to the pool level. These logistics are also illustrated in Figure 8.

IBC 2009 was used to determine if our designs in this area met code for life safety. From the code we determined that two stairway exits were needed and that the entire area would have to be protected with an automatic sprinkler system. Also, we will need to provide areas of refuge near each set of stairs for those in wheelchairs. We determined the occupancy of the pool area to be 180 and of the pool itself to be 54.[10] Based on these occupancies, a minimum width of 48 inches is needed for stairways.[10]

Considering that the pool is located within the school facility, our team addressed the potential that the school board will elect to omit the pool for economic reasons. If this were to occur, our team recommends continuing with the current design and construction as planned. The only exception is that the actual pool volume (which would be filled with water) would not be excavated. The school district would then have a very accessible, spacious, and flexible area with which to decide further use. Possible usages include but are not limited to: additional classrooms, elementary-level laboratories, exercise areas, or community spaces depending on the school district's wishes. If this does not appeal to the school board, our design team is prepared to adjust design so as to not include the pool area systems. For details regarding the pool cost breakdown, please see the Construction Report.

Green Roof/Outdoor Classroom

The competition program also mentioned the possibility of including a green roof on the elementary school. Our team saw this as an opportunity to not only include a unique sustainable feature, but also create a one-of-a-kind learning environment for the students. The green roof is located on the east wing roof as previously indicated in Figure 2 and will be accessible from the large group instructional area on the third floor. This space will provide the students with a unique opportunity to learn from nature and building systems, and strongly hits on our goal of using the school as an educational tool. Sustainable features often require the greatest level of collaboration, but when systems successfully come together, the unifying result is often a unique and beautiful display, such as the image in Figure 10.

Structural, maintenance and constructability concerns must be addressed when considering a green roof. Increased on-site materials and steel sizes are needed. Added weights due to increased dead and live loads on the roof will lead to increased steel sizes for the East wing. One major constructability concern is quality control. It is essential that the roof be watertight before installing the green roof vegetation. Leak detection tests and on-site inspections will take place throughout the construction process, ensuring that the membranes are watertight and able to perform as needed.

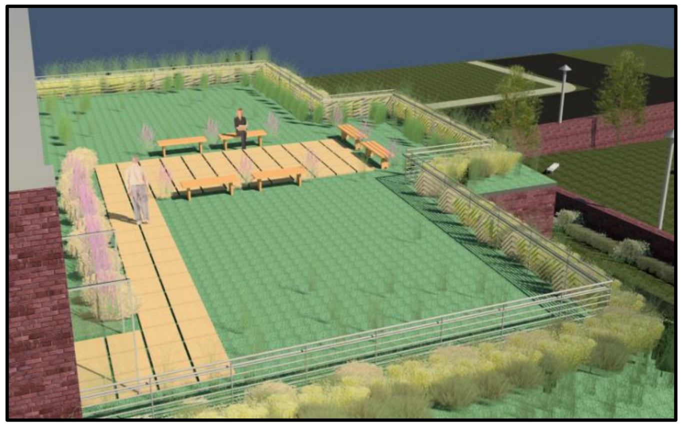


Figure 10: Green Roof Rendering from Revit

Additionally, the added insulation of the green roof can reduce the heat island effect, minimizing impacts on local microclimates and wildlife as well as protect and prolong the life of the roofing membrane. By shielding the roofing materials from wind and weathering effects, the roofing system will last longer without repair or replacement.

The added value of including a green roof above the East wing can be viewed as justification of additional costs. The cost differences between a typical roofing system and a green roof system can be seen in Table 2.

Table 2: Green Roof Cost Comparison

	Conventional Roofing System	Green Roofing System
Structural Steel	$73,660.00	$92,075.00
Structural Concrete	$0	$5,228.93
Roofing Materials	$29,716.50	$108,060.00
	$103,376.50	**$205,363.93**

While the green roof does lead to additional costs, many benefits exist in implementing a green roof system. Aside from the aesthetic effects of the green roof, green roofs lead to significant site and environmental benefits. Typical building roof systems increase impervious surface area on a given site. This increases the site water run-off to local stormwater sheds and can stress local infrastructure. Green roofing systems can substantially decrease water run-off. One major geotechnical concern for this project was the risk of sinkholes. The green roof will aid in mitigating this risk by reducing stormwater runoff through absorption and placing a smaller burden on local storm drains.

As a design team, we focused on blending elementary school design with student curriculums. Our facilities were designed with student success in mind. It is our team's recommendation to implement the green roof on the east wing as the associated costs do not outweigh the learning opportunity and flexibility provided to the students.

Security

Security played a crucial role in our team's design of the elementary school. Reading has had a recent history of crime, coming in at over double the Pennsylvania and national average for violent crime index the past ten years, as seen in Appendix G. Therefore, it was essential to emphasize security in our elementary school design. This security design was split into two components—exterior and interior. Although they are categorized differently, both components act together to create a safe and secure environment for the proposed Reading Elementary School.

In order to obtain ideas for site security design, we consulted the FEMA 430 standard for Site and Urban Design for Security.(11) In the standard, there is heavy emphasis placed on "three layers of defense" for site security. The first layer of defense refers to the site perimeter while the second and third layers apply to the area surrounding the building and the building itself, respectively.(11) Our design team took this concept and applied it to our elementary school design.

Exterior/Interior Security

The first layer of defense, as discussed in the FEMA 430 standard, applies more to prisons and government buildings where more severe security threats are present.(11) However, we still utilized this concept at the east end of the site around the proposed playground and existing baseball field. These areas, expected to be populated with children, will be surrounded by passive concrete barrier walls with an aesthetically-pleasing brick veneer finish as seen in Figure 11. These reinforced concrete walls accomplish a variety of security-related objectives. The first, and perhaps most obvious, is that they provide a barrier between the playground and the street. Not only will this keep children from wandering into the street, but it will also prevent vehicles from swerving onto the playground in the case of car accidents. As also seen in Figure 11, the only sight line into the playground occurs at the east entrance of the school, allowing the security room full visibility into the playground to monitor activity.

Figure 11: Concrete Barrier Walls Surrounding Playground

Our team also seeks to use these walls as an advantage in ballistics-related defense. Through talking with engineers and architects who have designed buildings in the Reading, Pennsylvania area, we have found that drive-by shootings have become an issue in the city.(12) Running preliminary ballistics calculations, we found that walls on the east side of the site would need to be approximately 5'-0" high to prevent bullets from a drive-by shooting from hitting the top of the school. Also, at a 12-in. thickness, the concrete walls are adequately thick to prevent bullet perforation per UFC 4-023-07.(6)

Not only do the walls enhance security, but they can also function as an educational tool, which relate to our team's design goal. For example, the walls can be inscribed with educational or inspirational concepts to be viewed by students. For the aforementioned reasons, it is our firm belief that the playground area can and will become a focal point of the surrounding area and will certainly be a positive mark on the community.

The second layer of defense, in our case, refers to security lighting and cameras that will be employed outside the building. Ensuring that key areas on the exterior of the building are well lit greatly enhances protection against intruders and suspicious activity. The security lighting will be used in conjunction with security cameras monitoring areas of interest along the perimeter of the site. Pole mounted LED luminaires illuminate the site to illuminance levels recommended by The Lighting Handbook produced by the Illuminating Engineering Society, as seen in Figure 12.[13]

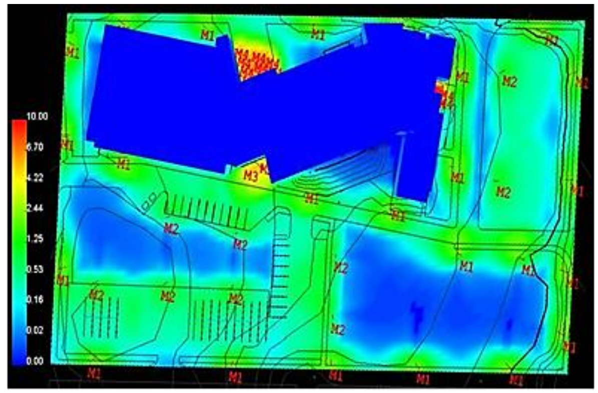


Figure 12: Site Illuminance Pseudo

For the third layer of defense to be used along the exterior of the building itself, our design team has decided to employ vestibules with card swipe access in conjunction with automatic-locking doors. We plan to use a security system which electronically records time and card identification number whenever a card is swiped so that the cause of any possible incident can be more easily traced.

For security inside the elementary school, our team has agreed to use gates blocking off corridors after school hours, a tactic traditionally used in elementary schools. However, community areas such as the multipurpose area, community room, and pool will still be accessible. Through the use of interior security cameras and a main security room, main areas inside the school can be viewed at all times to monitor activity during and after school hours.

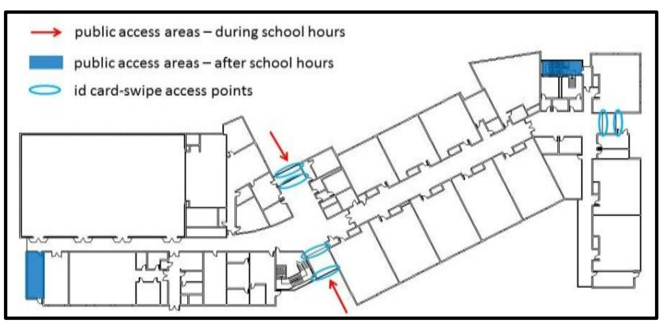


Figure 13: Security Logistics

Public Access Plan

In the wake of recent tragic events such as the Sandy Hook Elementary School shooting, our team has also developed a plan to control and monitor the public access into the building during school hours. The public is permitted access during school hours through the main entrances located in the core area of the first floor (see Figure 13), to provide a direct line-of-sight between the administration to the public entering the school. One wishing to enter the school must be allowed into the building by the administration. Once the administration has verified the person wishing to enter through a security camera feed, the visitor can enter the administration area. I.D. card-swipe is required outside and within the vestibules to further control access into the area. The public will be granted access to other areas of the building after school hours. Numerous security strategies were explored to provide safety to students in the event of an emergency intruder. However, we decided the most effective security strategy was to monitor and control the public access into the building.

LEED Certification

A U.S. Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) certification was pursued for Reading Elementary School. Our team focused on LEED early in the design process because of the importance stressed by the school board.

Through adding alternative forms of transportation, reducing stormwater runoff, and mitigating heat island effects we achieved 18 LEED credits under the sustainable site (SS) category.(14) The mechanical design allowed for an additional 28 credits in both the energy and atmosphere (EA) and the indoor environmental quality (IEQ) categories.(14) These points were achieved by demonstrating a reduction of energy consumption over the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) baseline case. Please refer to Figure 14 and Appendix F for detailed LEED credit breakdown and analysis.

Through the use of BIM technologies and coordination the project earned 58 LEED credits and achieved a LEED Silver certification.(14) It is essential to achieve LEED certifications in our public facilities as we strive towards energy independence and net zero facilities. An educational tool, such as an elementary school, will help to better inform the Reading community so they understand their carbon footprint.

LEED Scorecard

	LEED Credits
Sustainable Sites (SS)	18
Water Efficiency (WE)	6
Energy & Atmosphere (EA)	15
Materials & Resources (MR)	4
Indoor Environmental Quality (IEQ)	13
Innovation in Design (ID)	2
Regional Priority (RP)	0
Total LEED Credits	**58**

Figure 14: LEED Certification & Summary Scorecard

Site Water Management

One concern for our site is that it is in a region of karst topography and prone to sinkholes. This matter cannot be overlooked when designing the site drainage and foundation system. There are potential problems that can arise during and post construction. Adding additional impermeable surfaces to the site increases the risk of sinkhole activity if water runoff is not properly managed. One main way to mitigate the risk of sinkholes, especially in areas of karst terrain, is to properly manage site water.(15) Our design team has chosen to alleviate this concern in a sustainable fashion by adding a rainwater collection system to the design. This system will take advantage of the 27,400 ft^2 of catchment area on the roof and complement Reading's climate. The rain water storage tank and related equipment is located in the basement mechanical room. The water flows by gravity to the storage area and is used to offset toilet and site irrigation water. This system can collect an estimated 613,000 gallons of rainwater annually. The rainwater system combined with low-flow plumbing fixtures will save the school district $4,000 annually over standard plumbing fixtures. Not only does this system save the school district money but will also mitigate the risk of future sinkholes and potential structural damage to the foundation system. Please refer to Figure 15 and Appendix E for rain collection area and water usage.

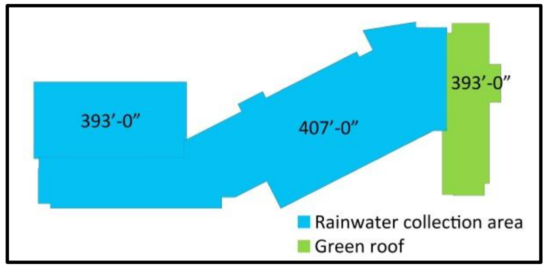


Figure 15: Roof Rainwater Collection Area

Conclusions

Overall our design team created a high performance elementary school that allows for flexibility of uses and enhances the community of Reading, Pennsylvania. Each discipline focused on the project's end goals and uses throughout the design. This collaboration leads to a building that is greater than the sum of its parts and a truly integrated design. The Charles Pankow Foundation Annual Architectural Engineering Student Design Competition goals of improving the performance of building design through advancing integration, collaboration, communication, and efficiency were also met. This project allowed our design team to gain a better understanding across multiple disciple design. Understanding the professional relationships that exist among the trades is critical for an integrated design. Through the use of our BIM execution plan, collaboration meetings, and collaborative work environment, we were able to accomplish the foundation's goals.

Specific project goals to design a high performance building, to achieve a LEED certification, and to provide a realistic budget were met. Through an integrated approach we designed high performance building enclosure that led to decreased energy though maximizing daylight and minimizing solar heat gain. This pre-cast system cuts construction time and costs while contributing to our pursuit of LEED certification. Our project achieved a LEED Silver certification. Project cost was considered non-negotiable for this project to minimize the stress put on the Reading community. We set out to build a cost effective school and were successful. Our final budget values come in at 216.44 $/ft^2 which is under the Northeast U.S. average for similar facilities.

Without the assistance of BIM and a collaborative effort this project would not have been as successful. Traditional independent discipline design limits project concerns to each specific engineering team. A collaborative design team can focus on owner and user goals which leads to higher owner satisfaction. Through integration we created an elementary school that will give Reading, Pennsylvania's students a better place to grow and learn while also bettering the community.

In addition to the attached appendices, please refer to the provided drawings for plans, images, perspectives, and renderings regarding unique spaces in the school. Also, please refer to specific option reports for more detailed information regarding structural, mechanical, lighting/electrical, and construction systems and procedures.

SECTION 2: SUPPORTING DOCUMENTATION

Appendix A: Lessons Learned

Throughout the design development process, our team learned a multitude of lessons. We acquired a great deal of admiration for designing a building from "scratch" especially using an integrated project delivery method. A lot of time and thought goes into the early schematic design phase to ensure all team members are on the same page.

Along the same lines, we learned that decisions within an individual discipline, although seemingly minor, can greatly affect other disciplines. For example, moving a lateral hybrid wall from one bay to another can cause many problems for the mechanical and lighting/electric engineers. The new location of the frame can interfere with windows or proposed locations of "punching" for ducts and pipes.

Perhaps the most important finding we discovered during the design process deals with communication. Even with all the new advances in technology, the best form of communication occurs when all members of the team sit around a table and discuss an item in person. This method leads to the most efficient decision-making process. Similarly, the best way of explaining a system or idea to the team is by graphical means. Pictures, diagrams, and models get the idea across much better than text, especially when discussing a concept with a teammate in another discipline.

We also learned that before delving deep into design of a system, it is very important to research and understand exactly how the system works. Fortunately, all of our team members took this approach and it benefited us greatly. We now have a thorough understanding of the engineering logic behind our building and it has saved us valuable time in the design process.

The final, and perhaps most important, lesson we learned is to reach out to industry professionals. Many times, sending an e-mail or phoning an established and respected engineer can be very intimidating, but we have found that many professionals are always happy to help and give advice. Through communication, not only can you gain engineering knowledge, but you can also establish very valuable industry connections.

Appendix B: Team Processes and BIM Objectives

Decision Making and Collaboration

Our team determined early on that communication and coordination were paramount to project success. After setting our team goals, we developed a general decision making process as well as a weekly coordination meeting schedule to ensure our team's schedule and goals were met. For our general decision-making map, shown in Figure B-1, we wanted to encompass any possible questions or assessments that may arise during the design process.

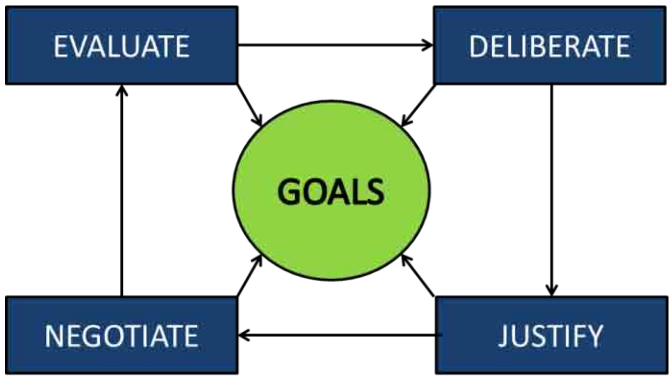
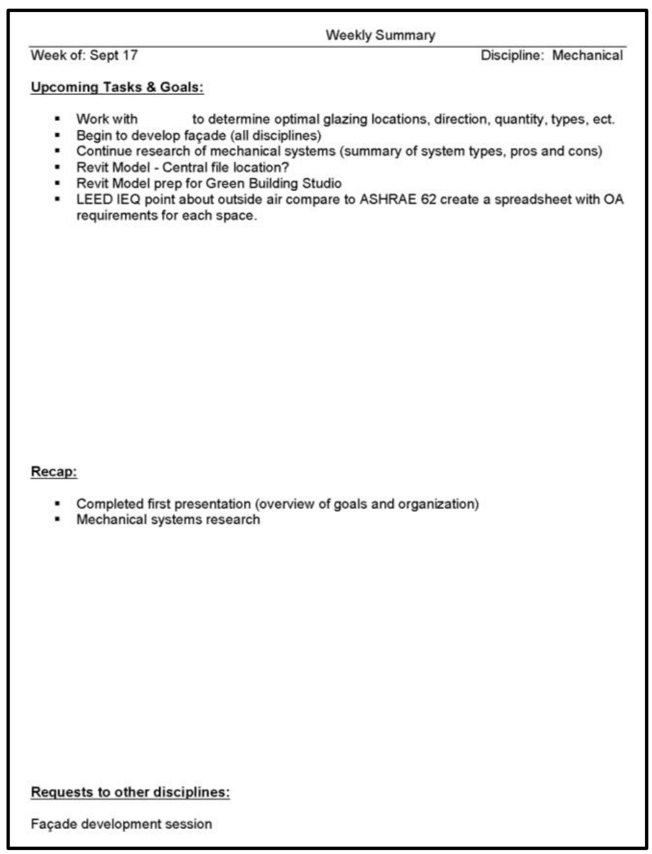


Figure B-1: Decision Making Process Map

The purpose of this decision map was to always remind our team that every choice needed to revolve around our team goals. We wanted to evaluate each decision, deliberate on the positives and negatives, justify the benefits of that decision, and create a compromise between trades if necessary. By following this process in our decision making, we were able collaborate and come up with the best solutions to any design problems.

Another important aspect of our team's coordination was our weekly coordination meetings. As shown in Figure B-2, our weekly meetings were used to discuss the upcoming tasks and goals of the differing options, summarize the previous work week, and make any requests necessary to the other design option teams for the upcoming week. By holding these meetings in a consistent manner, we were able decrease lead/lag between design options, increase information exchange, and look ahead to immediate schedule deadlines and project milestones. These meetings not only generated team integration, but also allowed us discuss and solve any issues that arose the week before.



Weekly Summary

Week of: Sept 17 Discipline: Mechanical

Upcoming Tasks & Goals:

- Work with to determine optimal glazing locations, direction, quantity, types, ect.
- Begin to develop façade (all disciplines)
- Continue research of mechanical systems (summary of system types, pros and cons)
- Revit Model - Central file location?
- Revit Model prep for Green Building Studio
- LEED IEQ point about outside air compare to ASHRAE 62 create a spreadsheet with OA requirements for each space.

Recap:

- Completed first presentation (overview of goals and organization)
- Mechanical systems research

Requests to other disciplines:

Façade development session

Figure B-2: Weekly Coordination Meeting Minutes

Organization

Utilizing electronic file storage is obviously the preferred method of saving and maintaining project information, whether it be calculations, models, or other documents. However, without an organized file structure, the collaboration and integration process becomes much more difficult. This is why our team created a uniform electronic file structure complete with a numbering system in order to make file storage much easier and more organized. It also allows easier navigation through each discipline's folders. For example, there were many times when one discipline needed to extract data from another discipline's file location (e.g. mechanical designers looking for structural framing depth in a certain location in order to determine duct elevation). A snapshot of our team's file structure which helped us achieve these goals can be seen in Figure B-3.

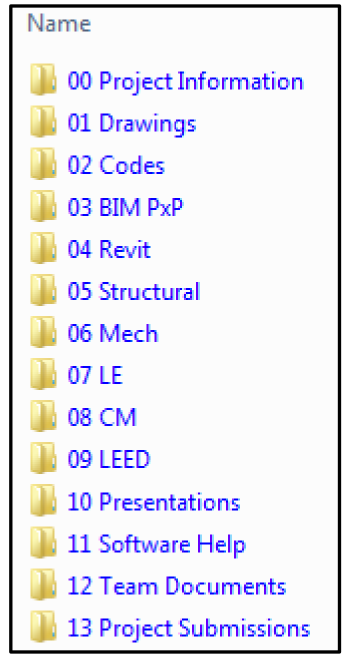


Figure B-3: Electronic File Structure

Team Schedule

The Design Process Critical Path Schedule seen in Figure B-4 shows the overall activity and work flow of our group's project from start to finish. The major activities are color coded by discipline and show the relationships between the design options. This schedule was an ongoing effort and was created and updated as our group progressed. One of the major takeaways from this schedule is the lead/lag relationship between the options. If we would have created this long term schedule early on in the project, we could have been better prepared for the items in which other disciplines would rely upon and thus more effectively managed our time. Creating this schedule gave our group a chance to look back at the overall design process we used and understand and build upon some of our shortcomings.

The schedule is an effective visualization of the discipline collaboration that took place during the project. Many activities throughout the design process we dependent on multiple disciplines and decisions had to be made to keep our group on task. Some activities, such as façade window location and solar heat gain, required the attention of multiple disciplines and those decisions needed to be made or would affect the delivery of following items. Clash detection could not take place until all disciplines finalized their Revit models but needed to take place early enough to allow time for clash reviews. Creating this schedule of our group's activities proved to be an important means of progress tracking.

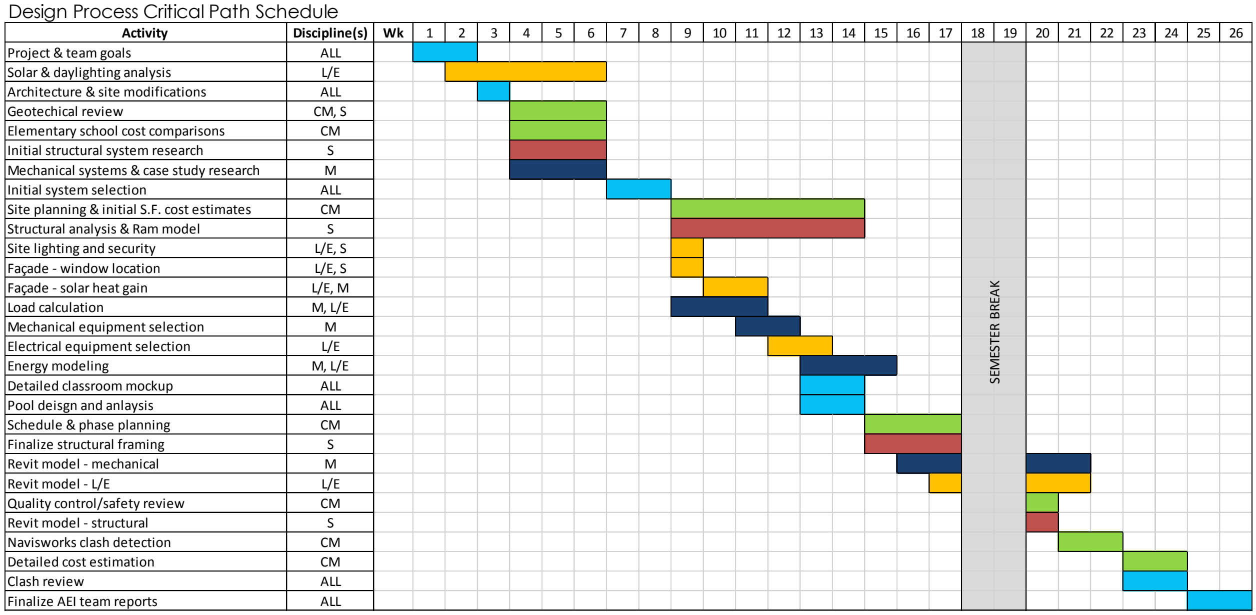
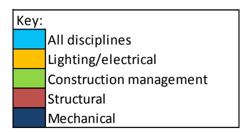


Figure B-4: Design Process Critical Path Schedule



BIM Uses and Objectives

Early in the design process, our team got together and determined how we were going to use different BIM tools. Our goal was to recognize early on what BIM programs would be most useful as well as brainstorm what activities we planned on carrying out through the design process. The BIM Use Priority Chart, seen in Table B-1, represents our team's activities and what BIM programs could help us to meet our project goals.

Table B-1: BIM Use Priority Chart

Priority	Goal Description	BIM Uses
HIGH	Integrated building design	Worksharing, Central models
HIGH	Integrated model	Revit
HIGH	Minimal clashes	Navisworks
HIGH	Structural design/modeling	RAM, Revit
HIGH	Energy modeling	Green Building Studio, Revit
HIGH	Quantity takeoffs	Revit
HIGH	Cost estimating	Revit
HIGH	Project documentation	Revit
HIGH	Presentation graphics	3ds Max, Navisworks, Revit
MED	Lighting calcs	Elumtools
LOW	Renderings	3ds Max, Navisworks

Creating this chart allowed our team to organize and prioritize our team's activities based on what was most important to accomplishing our design goals. Early organization ensures that our team can be on the same page and plan work accordingly.

Another major part of our BIM execution plan was creating a process map that would visually show the steps we planned to take in designing the Reading Elementary School. The process map in Figure B-5 shows the four phases of our design process along with what major activities would be going on within them. The map also shows the dependency certain activities have on others.

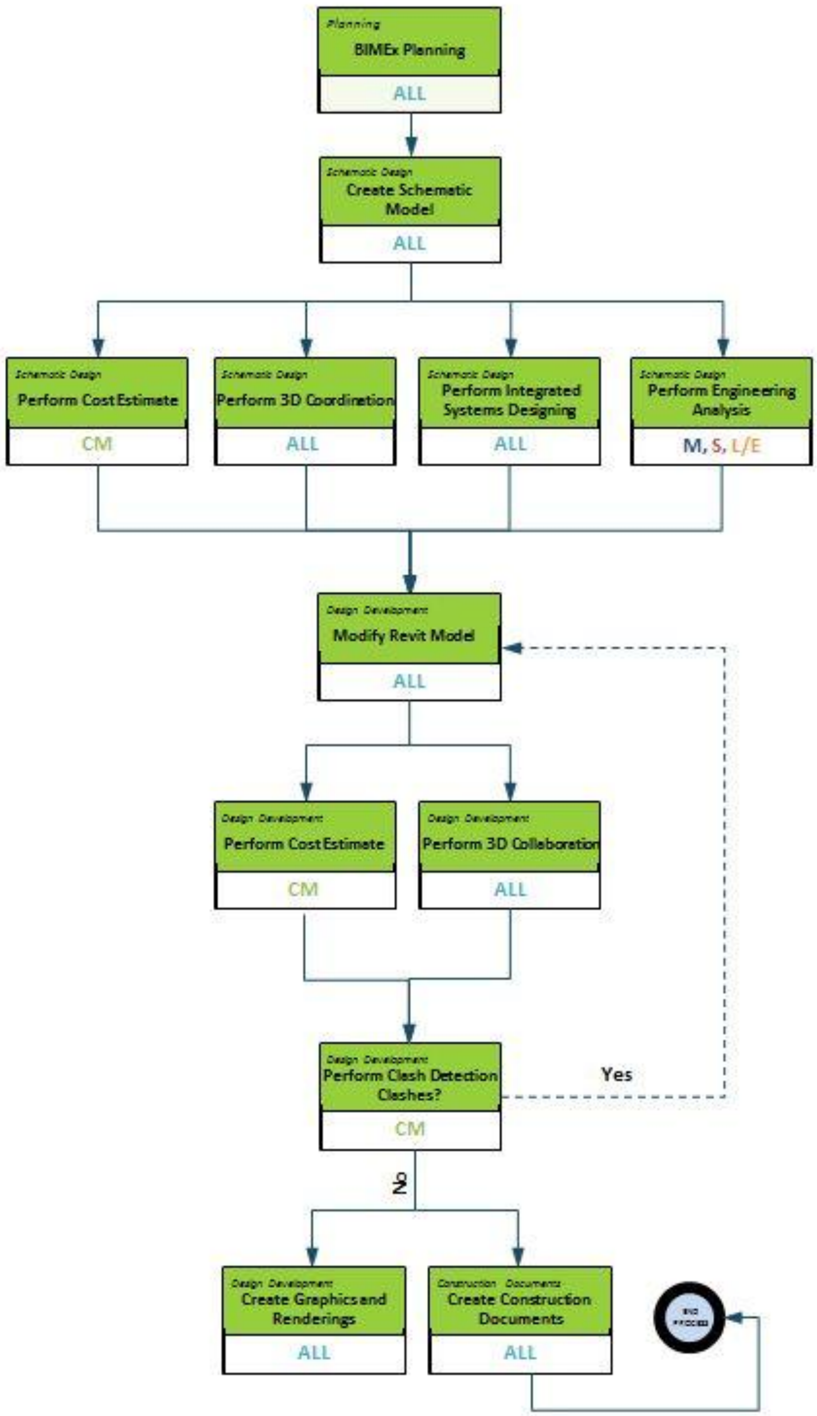


Figure B-5: BIM Process Map

Appendix C: Project Schedule and Cost Estimate

Schedule and Milestones

The schedule in Figure C-1 displays our construction schedule with highlighted milestones. This schedule was created by taking into consideration the start and finish dates based on the months of school operation and filling in important milestones in between.

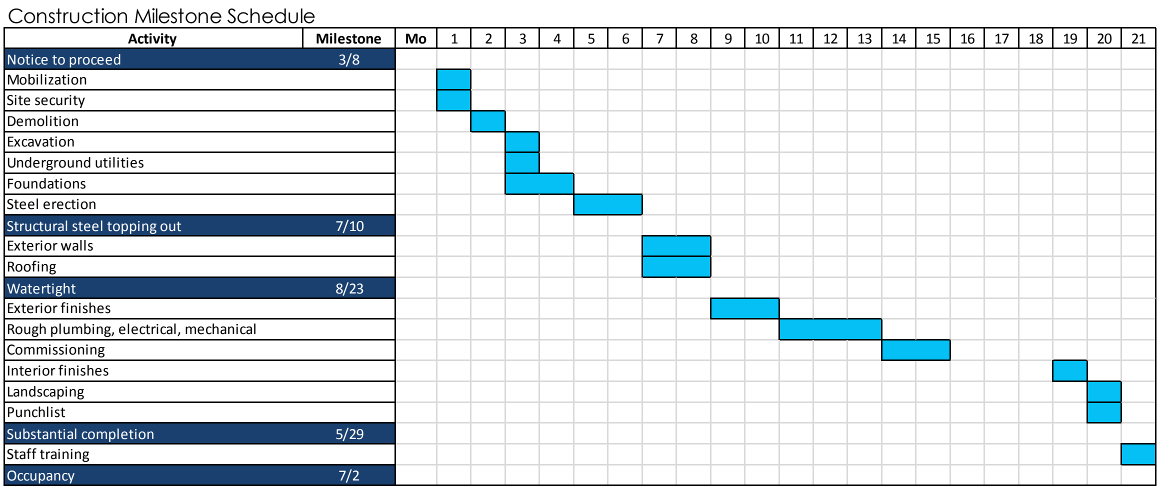


Figure C-1: Construction Milestone Schedule

Below are some of the milestones that we needed to achieve to meet our goal of on-time completion.

- **Excavation – April 8, 2013** – We chose this as our beginning excavation date for a number of reasons. First, we can expect the ground to be thawed in this location by April which will make excavation much easier. Also, we plan on following excavation with our foundation work, which will entail possible drilling and placing concrete. By using this date, we can ensure that we will not be forced place concrete in freezing conditions or drill foundations in a few feet of snow.
- **School Year Ends – May 1, 2013**
- **Structural Steel Topping Out – July 1, 2013** – Structural steel topping out was scheduled based on what work activities had to follow as well as our watertight schedule goal. We wanted to allow enough time for masonry construction as well as our precast panel erection to still meet the goal established.
- **Watertight - September 30, 2013** – We selected this as the milestone date for when we expect the building structure to be watertight because we would be able to save a lot of money by not supplying temporary heat if we can have the building enclosed as well as store materials in the building to protect against harsh weather that falls after October.
- **Substantial Completion – June 2, 2014** – It is important that we leave enough time to turn the building over and provide adequate training to facility managers who will need to learn how to work the various heating, cooling, lighting, and security systems of the building.
- **School Year Begins – August 25, 2014**

Cost Analysis

A detailed cost analysis was performed for the construction of the Reading Elementary School based on the engineering systems our team has designed and implemented. Table C-1 summarizes the cost breakdown.

Table C-1: Elementary School Cost Breakdown

READING ELEMENTARY SCHOOL CONSTRUCTION BUDGET				
Square Footage: 82433		Year: 2013		
Category	**Description**	**Cost**	**Cost/SF**	**% of Original Contract**
A. Substructure	A10 Foundations	$200,526.52	$2.43	1.56%
	A20 Basement Const	$792,473.48	$9.61	6.15%
B. Shell	B10 Superstructure	$2,098,250.00	$25.45	16.30%
	B20 Exterior Enclosure	$1,307,574.00	$15.86	10.16%
	B30 Roofing	$564,278.00	$6.85	4.38%
C. Interiors	C10 Interior Const	$1,436,344.00	$17.42	11.16%
	C20 Stairs	$287,268.80	$3.48	2.23%
	C30 Interior Finishes	$1,149,075.20	$13.94	8.92%
D. Services	D10 Conveying	$76,947.00	$0.93	0.60%
	D20 Plumbing	$705,347.50	$8.56	5.48%
	D30 HVAC	$2,039,095.50	$24.74	15.84%
	D40 Fire Protection	$294,963.50	$3.58	2.29%
	D50 Electrical	$1,577,413.50	$19.14	12.25%
E. Equipment & Furnishings	E10 Equipment	$259,696.13	$3.15	2.02%
	E20 Furnishings	$86,565.38	$1.05	0.67%
F. Special Construction & Demolition	F10 Special Const	$0.00	$0.00	0.00%
	F20 Selective Building Demolition	$0.00	$0.00	0.00%
Subtotal		$12,875,818.50	$156.23	100.00%
Time Adj. Factor		$289,461.76	$3.51	2.25%
Add-Alternate (Pool)		$1,597,569.30	$19.38	12.41%
General Conditions		$1,340,743.00	$16.26	10.41%
Taxes		$772,549.11	$9.37	6.00%
Fee		$643,790.93	$7.81	5.00%
Bonds & Insurance		$321,895.46	$3.90	2.50%
TOTAL		**$17,841,828.06**	**$216.44**	

Our total building construction cost was found to be $17,841,828.06 with a square foot cost of approximately $216/SF. Cost effectiveness was an especially important factor in this project and to ensure this, we compiled square foot cost data from various resources to determine where our design fit in. As seen in Table C-2, the average elementary school cost was about $237/SF. Our square foot cost of $216/SF from Table C-1 makes sense based on this compiled data.

Table C-2: Comparable Building Cost Estimates

Comparable Building Cost Estimates								
Data	**Year**	**Location**	**S.F.**	**Price**	**Per S.F.**	**Location Factor**	**Time Factor**	**Adjusted S.F. Cost**
D4 Estimate	2013	Reading, PA	82,433	$17,376,074	$210.79	1.00	1.00	$210.79
R.S. Means Costworks	2012	Reading, PA	82,433	$17,152,500	$208.08	1.00	1.02	$212.24
Clearview Elementary School	2002	Hanover, PA (Near York)	43,638	$6,887,822	$157.84	1.03	1.56	$253.62
School Planning & Management	2011	National	75,000	$14,800,000	$197.33	0.99	1.06	$207.08
School Planning & Management	2011	PA,NJ,NY	90,000	$26,000,000	$288.89	0.99	1.06	$303.16
							AVG	**$237.38**

Appendix D: Building Enclosure

Façade Development

Curtain wall is located along the façade enclosing circulation areas in the school. Curtain wall enclosing the large group instruction area provides unobstructed views onto the green roof. Curtain wall facing west was limited in order to avoid adding to the peak mechanical loads.

The following façade systems were analyzed early in the design process to better understand how façade treatments affected solar heat gain and daylighting. Figure D-1 models a bare window along the southeast façade without window treatments. The solar heat gain characteristics are graphed throughout the day. The DA_{300} performance of the classroom (28'- 0" x 40' - 0") is also provided. Figures D-2, D-3, and D-4 show the impact of different shading conditions on heat transfer and the amount of daylight in the southeast classroom. The façade was designed to balance heat transfer, glare, aesthetics, initial and lifecycle costs, and daylight harvesting to benefit the learning environment.

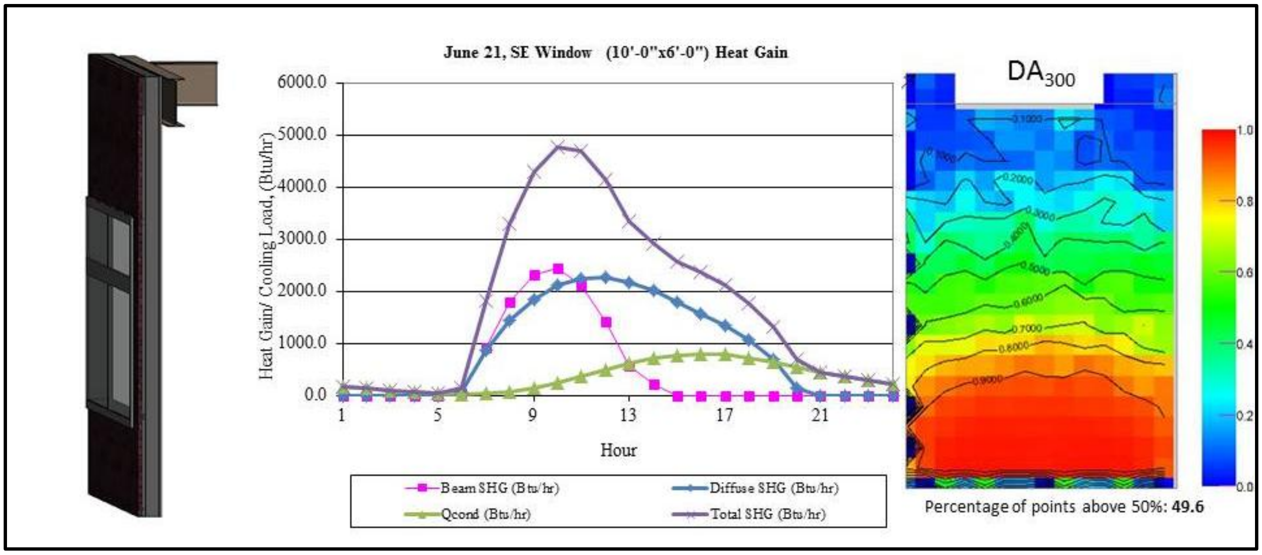


Figure D-1: Southeast-Facing Window Performance (No Window Treatment)

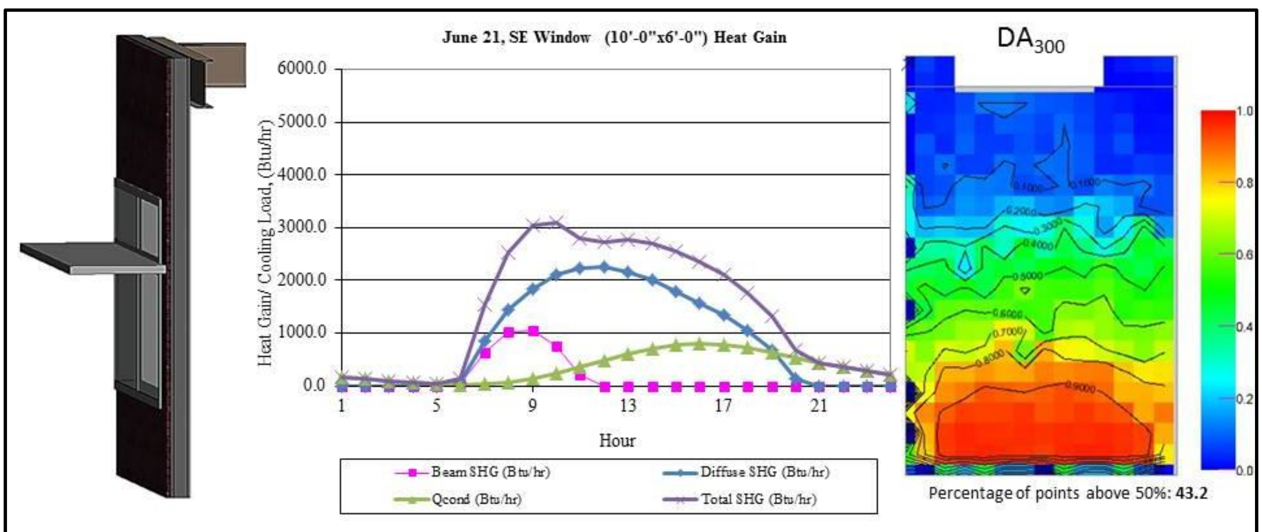


Figure D-2: Southeast-Facing Window Performance (Exterior Light Shelf)

AEI Team 10-2013

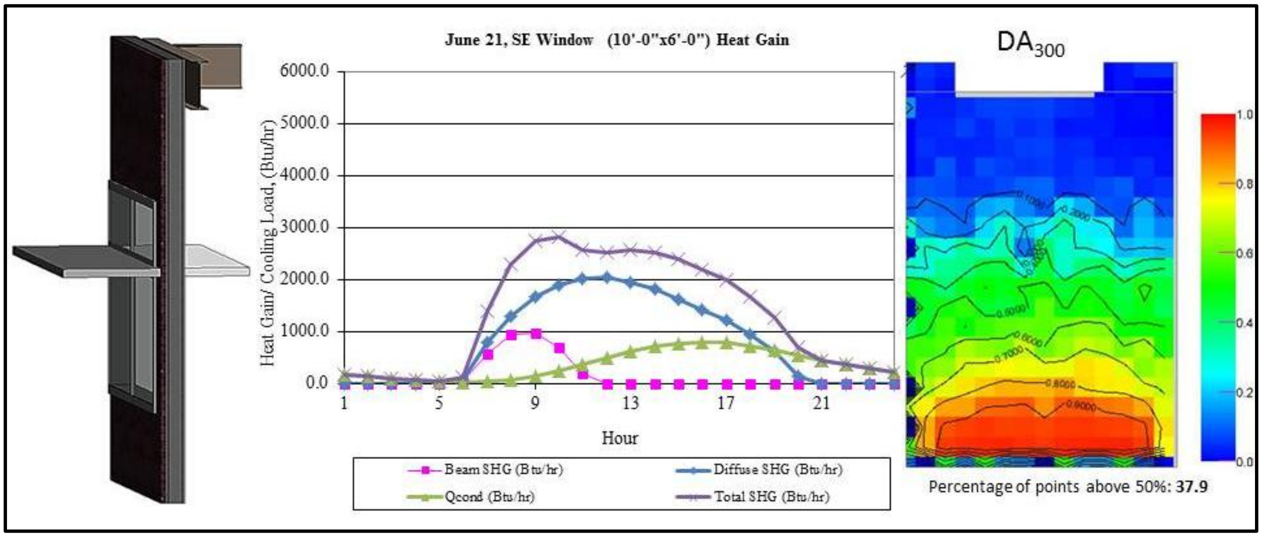


Figure D-3: Southeast-Facing Window Performance (Interior and Exterior Light Shelves)

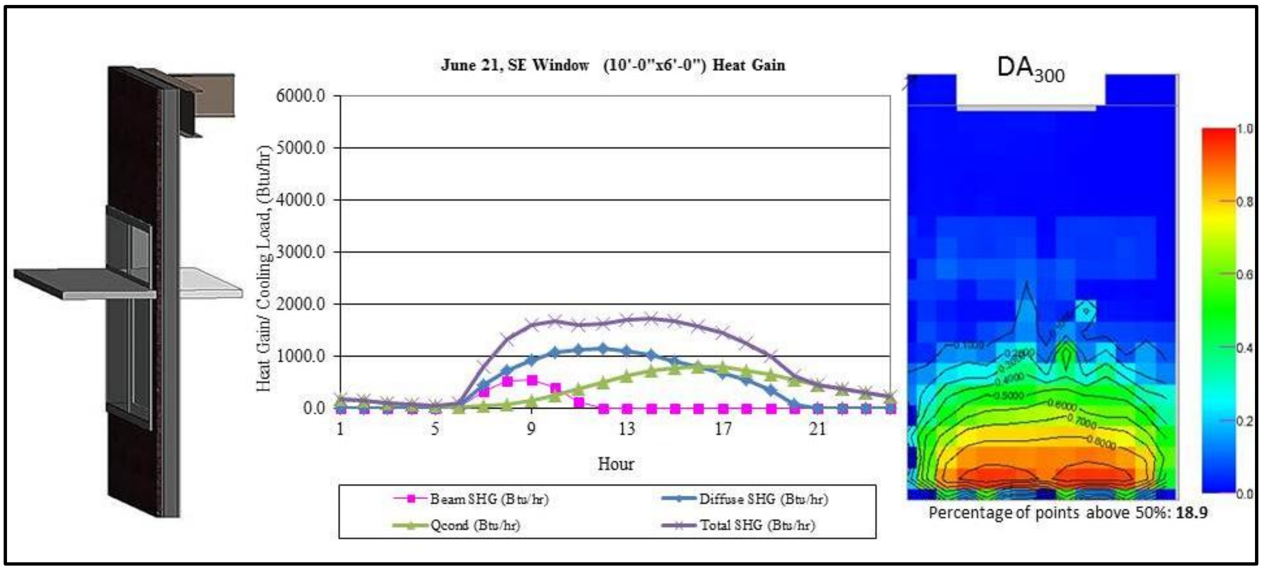


Figure D-4: Southeast-Facing Window Performance (Interior and Exterior Light Shelves with Interior Shades)

The proposed window design along the southeast façade incorporates an exterior and interior light shelf with interior shades. The exterior and interior light shelf reduce the solar heat gain in the classroom, resulting in greater energy savings than the potential luminaire dimming energy savings that would be expected from a bare window. The interior shades are provided to allow reduced light levels within the classroom as desired by each class. The aforementioned analysis was conducted for different building façade orientations to provide an energy efficient, cost effective, and comfortable learning environment.

Analysis of exterior shading fins along the north and east oriented façades proved less effective and do not warrant the cost or reduced view angles out of classroom windows. Additionally, initial conceptual clerestory systems on the 3rd floor demanded additional structural members throughout the building, therefore dramatically increasing construction cost and complicating the structural design.

Instead, skylight configurations were explored to contribute daylight to the interior of classroom spaces with the roof directly above allowing for additional energy savings. Commercial skylights were considered to be integrated into the roof of classrooms at two different locations (middle and back). The skylights considered were 4' – 0" x 4' – 0" with a 2' – 0" well depth. DAYSIM software was used to calculate the additional luminaire dimming energy savings and Skycalc was used to calculate the heat transfer losses through the skylights. Table D-1 summarizes the energy performance of the skylights throughout 18 different classrooms totaling 36 skylights (2 skylights per room). Cost savings are calculated based on $0.14 per kWh, $1.01/Therm, and $1,000.00 initial cost per skylight.

Table D-1: Building Skylights Luminaire Dimming Annual Energy and Cost Savings

Model	Dimming annual energy savings (KWh)	Heating and cooling annual energy losses (KWh)	Total annual energy savings (KWh)	Total annual cost savings
No skylights	6,516	0	6,516	$912.24
Skylights back	47,736	18,540	29,196	$4,087.44
Skylights middle	91,530	18,540	72,990	$10,218.60

The simple payback period was calculated for the skylights located in the back of the room. The skylights located in the middle of the room would be difficult to control the amount of daylight entering the classroom. This is especially important when a darker scene selection is desired for A/V viewing.

PP = I/A

Where:

PP =	simple payback period (years)	=	**8.8 years**
A =	incremental annual cash flow (annual savings)	=	$4,087.00
I =	initial investment	=	$36,000.00

The calculated simple payback period of 8.8 years proves to be an ineffective investment for the client. Additionally, there would be additional structural and labor costs to integrate the skylights into the proposed design of the building that are not calculated. The skylights were therefore excluded from the proposed building design.

SlenderWall Details[2]

Figures D-5 through D-8 show typical details as they apply to the proposed elementary school. Please refer to the Structural Systems Report and the Construction Report for more details regarding connections and construction sequencing.

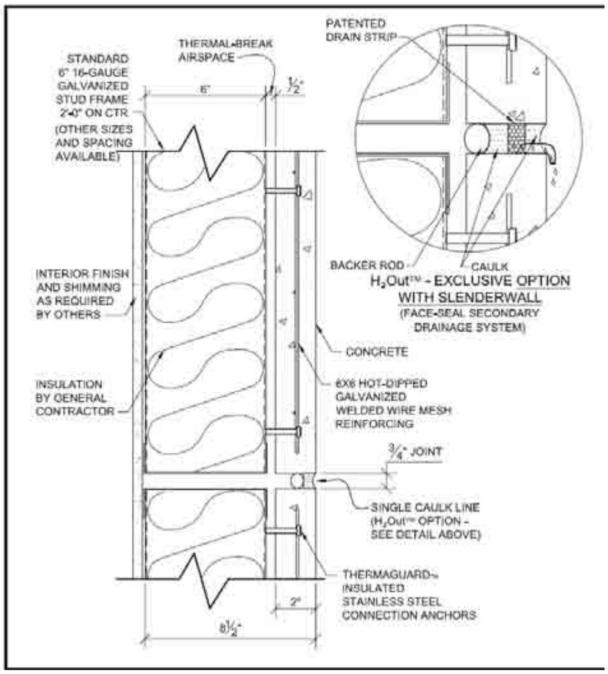


Figure D-5: Typical SlenderWall Section

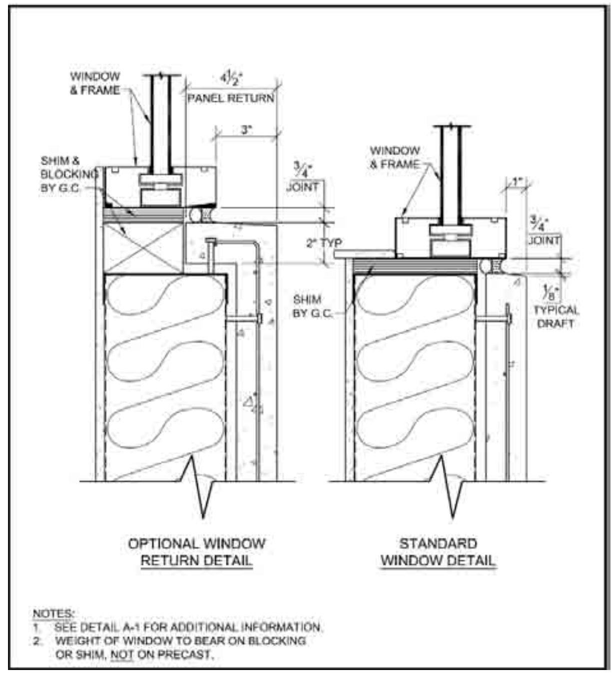


Figure D-6: Typical Window Detail

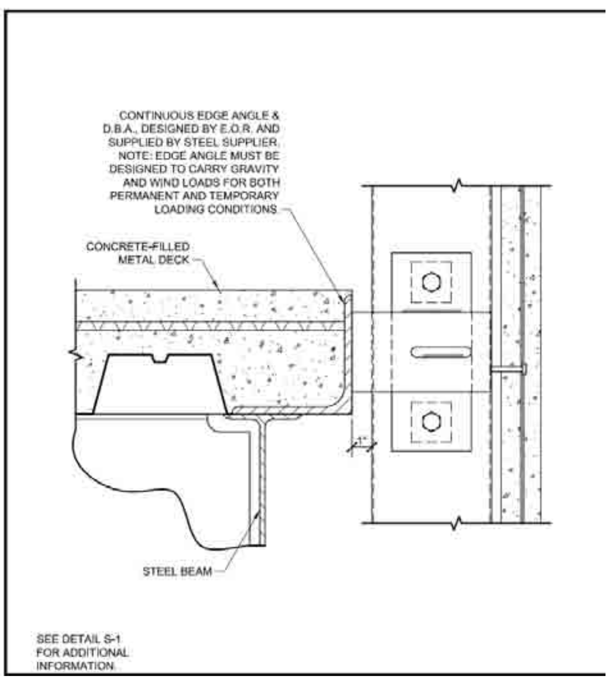


Figure D-7: Gravity Connection at Steel Edge Angle

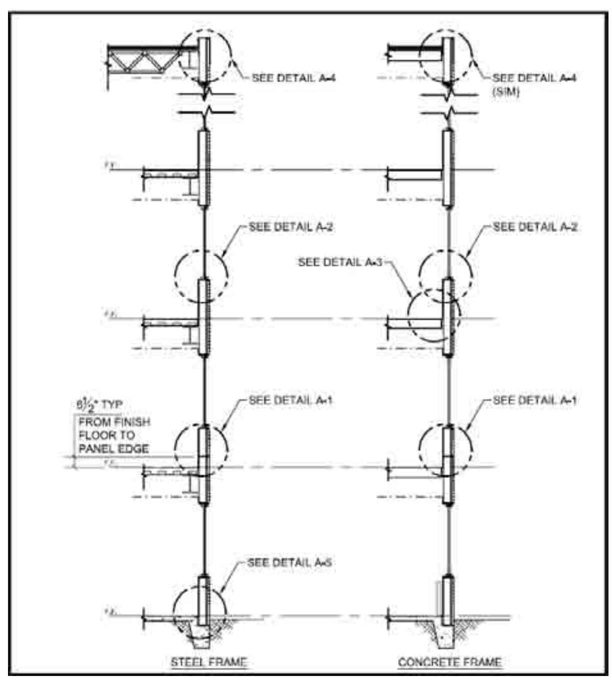


Figure D-8: Panelization Section (Steel Frame on Left)

Appendix E: Water Usage

Indoor water use was determined through estimation based on number of toilets, urinals, sinks, and showers located within the facility. The water use between standard and low-flow fixtures was compared and the water savings were calculated. The use of low-flow fixtures would save the school district nearly $2,400 annually. This information is outlined on the tables below:

Table D-1: Plumbing Water Savings Comparison

Type	Total	Efficiency	Percent of Indoor Usage (%)	Gal/yr	Annual Cost Savings ($)
Toilets	51	Low-Flow	9.6	230,118	1,399
Urinals	12	Low-Flow	4.8	114,491	696
Sinks	39	Hands-Free	1.2	27,729	169
Showers	6	Low-Flow	0.4	10,678	65
	Total Water Savings		**16**	**383,016**	**2,329**

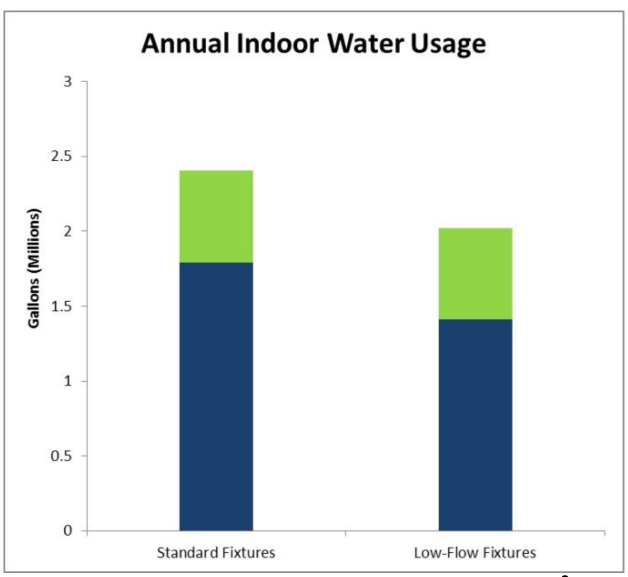
Table D-2: Water Usage and Costs

	Gal/yr	Annual Cost ($)
Indoor	2,007,969	10,616
Rainwater Collected	612,397	1,592
Net Utility	**1,395,572**	**9,024**

Assuming water price of $2.60/ kgal

The figure below highlights in green the potential annual water savings by using the rainwater harvesting system. This system will collect an annual 612,400 gallons that can be stored and used for site irrigation and waste water. This will save the school district $9,024 annually.

Figure D-1: Annual Indoor Water Usage & Potential Rainwater Collection



Potential Rainwater Collection

Catchment Area (ft^2) 27,400

Month	Rainfall [in]	Vol. [gal]
Jan	2.92	0
Feb	2.93	0
Mar	3.56	60,802
Apr	3.69	63,023
May	4.03	68,830
June	4.50	76,857
July	4.67	79,760
Aug	3.80	64,901
Sept	4.42	75,491
Oct	3.78	64,560
Nov	3.44	58,753
Dec	3.58	0
	Total	612,977

***Catchment Area = 27,400 ft^2**

Appendix F: LEED Analysis and Considerations

A USGBC LEED silver certification was earned for Reading Elementary School. The project required design teams to earn at least LEED certified status. Table E-1 shows a complete list of all LEED credits earned by our design team.

Table E-1: LEED Project Checklist

LEED 2009 For Schools New Construction and Major Renovations Project Checklist							
Sustainable Sites (SS)		**24 Possible Points**	**Possibility**	**Status**	**Discipline Lead**	**Page #**	**Point Estimate**
Prerequisite 1	Construction Activity Pollution Prevention	Required	Required	complete	CM	1	-
Prerequisite 2	Environmental Site Assessment	Required	Required	complete	CM	2	-
Credit 1	Site Selection	1	yes	complete	CM	3	1
Credit 2	Development Density and Community Connectivity	4	yes	complete	CM	4	4
Credit 3	Brownfield Redevelopment	1	yes	complete	CM	6	1
Credit 4.1	Alternative Transportation-Public Transportation Access	4	yes	complete	CM	7	4
Credit 4.2	Alternative Transportation-Bicycle Storage and Changing Rooms	1	yes	complete	CM	8	1
Credit 4.3	Alternative Transportation - Low-Emitting and Fuel-Efficient Vehicles	2	no	complete	CM	9	0
Credit 4.4	Alternative Transportation-Parking Capacity	2	yes	complete	CM	10	2
Credit 5.1	Site Development - Protect or Restore Habitat	1	yes	complete	CM	11	1
Credit 5.2	Site Development - Maximize Open Space	1	yes	complete	CM	12	1
Credit 6.1	Stormwater Design - Quantity Control	1	yes	complete	CM	13	1
Credit 6.2	Stormwater Design - Quality Control	1	no	complete	CM	14	0
Credit 7.1	Heat Island Effect - Nonroof	1	no	complete	CM	15	0
Credit 7.2	Heat Island Effect - Roof	1	yes	complete	M	16	1
Credit 8	Light Pollution Reduction	1	no	complete	L/E	18	0
Credit 9	Site Master Plan	1	no	complete	CM	21	0
Credit 10	Joint Use of Facilities	1	yes	complete	CM	22	1
						Subtotal	**18**
Water Efficiency (WE)		**11 Possible Points**					
Prerequisite 1	Water Use Reduction	Required	Required	complete	M	25	-
Credit 1	Water Efficient Landscaping	2-4	no	complete	M	27	0
Credit 2	Innovative Wastewater Technologies	2	yes	complete	M	29	2
Credit 3	Water Use Reduction	2-4	yes	complete	M	30	4
Credit 4	Process Water Use Recuction	1	no	complete	M	32	0
						Subtotal	**6**
Energy and Atmoshpere (EA)		**33 Possible Points**					
Prerequisite 1	Fundamental Commissioning of Building Energy Systems	Required	Required	complete	M	33	-
Prerequisite 2	Minimum Energy Performance	Required	Required	complete	M	35	-
Prerequisite 3	Fundamental Refrigerant Management	Required	Required	complete	M	37	-
Credit 1	Optimize Energy Performance	1-19	yes	complete	M	38	6
Credit 2	On-Site Renewable Energy	1-7	yes	complete	L/E	41	5
Credit 3	Enhanced Commissioning	2	yes	complete	M	42	2
Credit 4	Enhanced Refrigerant management	1	no	complete	M	44	0
Credit 5	Measurement and Verification	2	yes	complete	M	46	2
Credit 6	Green Power	2	no	complete	L/E	48	0
						Subtotal	**15**
Materials and Resources (MR)		**13 Possible Points**					
Prerequisite 1	Storage and Collection of Recyclables	Required	Required	complete	CM	49	-
Credit 1.1	Building Reuse - Maintain Existing Walls, Floors and Roofs	1-2	no	complete	CM	50	0
Credit 1.2	Building Reuse - Maintain Existing Interior Nonstructural Elements	1	no	complete	CM	51	0
Credit 2	Construction Waste Management	1-2	yes	complete	CM	52	1
Credit 3	Materials Reuse	1-2	no	complete	CM	53	0
Credit 4	Recycled Content	1-2	no	complete	CM	54	0
Credit 5	Regional Materials	1-2	yes	complete	CM	55	2
Credit 6	Rapidly Renewable Materials	1	no	complete	CM	56	0
Credit 7	Certified Wood	1	yes	complete	CM	57	1
						Subtotal	**4**

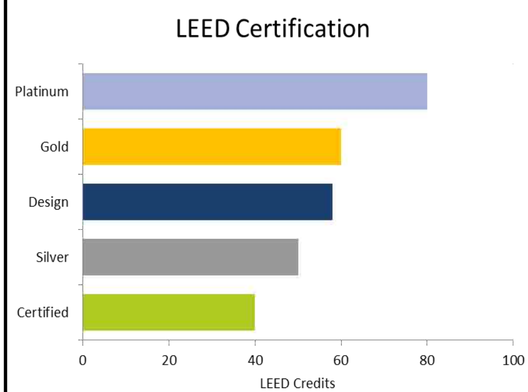
Table E-1: LEED Project Checklist (Continued)

Indoor Environmental Quality (IEQ)		**19 Possible Points**					
Prerequisite 1	Minimum Indoor Air Quality Performance	Required	Required	complete	M	59	-
Prerequisite 2	Environmental Tobacco Smoke (ETS) Control	Required	Required	complete	M	60	-
Prerequisite 3	Minimum Acoustical Performance	Required	Required	complete	M	61	-
Credit 1	Outdoor Air Delivery Monitoring	1	yes	complete	M	63	1
Credit 2	Increased Ventilation	1	yes	complete	M	64	1
Credit 3.1	Construction Indoor Air Quality Management Plan - During Construction	1	yes	complete	CM	66	1
Credit 3.2	Construction Indoor Air Quality Management Plan - Before Occupancy	1	yes	complete	CM	67	1
Credit 4	Low-Emitting Materials	1-4	yes	complete	CM	69	2
Credit 5	Indoor Chemical and Pollutant Source Control	1	no	complete	M	71	0
Credit 6.1	Controllability of Systems - Lighting	1	yes	complete	L/E	72	1
Credit 6.2	Controllability of Systems - Thermal Comfort	1	yes	complete	M	73	1
Credit 7.1	Thermal Comfort - Design	1	yes	complete	M	74	1
Credit 7.2	Thermal Comfort - Verification	1	yes	complete	M	75	1
Credit 8.1	Daylight and Views - Daylight	1-3	no	complete	L/E	76	0
Credit 8.2	Daylight and Views - Views	1	yes	complete	L/E	80	1
Credit 9	Enhanced Acoustical Performance	1	yes	complete	M	81	1
Credit 10	Mold Prevention	1	yes	complete	M	82	1
						Subtotal	**13**
Innovation in Design (ID)		**6 Possible Points**					
Credit 1	Innovation in Design	1-4	yes	complete	CM	83	1
Credit 2	LEED Accredited Professional	1	no	complete	CM	84	0
Credit 3	The School as a Teaching Tool	1	yes	complete	CM	85	1
						Subtotal	**2**
Regional Priority (RP)		**4 Possible Points**					
Credit 1	Regional Priority	1-4	no	complete	CM	87	0
						Subtotal	**0**
						Total	**58**

LEED 2009 for Schools New Construction and Major Renovations certifications are awarded according to the following scale:

Certified	40-49
Silver	50-59
Gold	60-79
Platinum	80 points and above

As previously discussed, Figure E-1 shows the Reading Elementary School's LEED rating as compared to the LEED status.



LEED Scorecard

	LEED Credits
Sustainable Sites (SS)	18
Water Efficiency (WE)	6
Energy & Atmosphere (EA)	15
Materials & Resources (MR)	4
Indoor Environmental Quality (IEQ)	13
Innovation in Design (ID)	2
Regional Priority (RP)	0
Total LEED Credits	**58**

Figure E-1: LEED Certification & Summary Scorecard

SS Credit 2: Development Density and Community Connectivity : 4 Points
Constructed on a site that, is located on a previously developed site, is within ½ mile of a residential area or neighborhood with density of 10 units per acre, is within ½ mile of at least 10 basic services (see map below), and has pedestrian access between the building and the services.

Figure E-2: Community and Connectivity Map

SS Credit 4.1:
Alternative Transportation-Public Transportation Access : 4 Points
Have a bus stop for two or more bus lines within ¼ mile of the main entrance of the school in addition to providing walking or biking lanes from the school to the transit lines.

- School bus system can count as one, and BARTA has a route that goes along 13th street. Either use existing stop (2) or add stop along route.

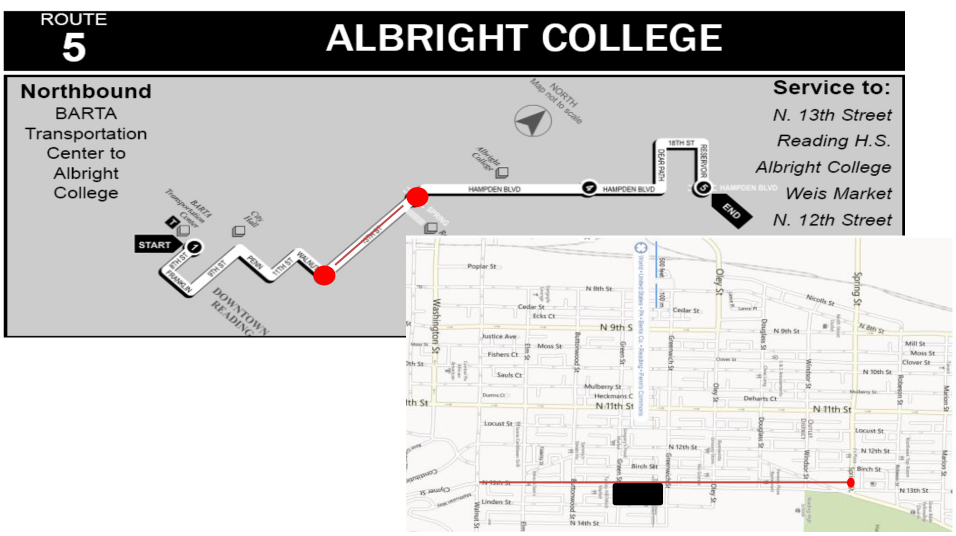


Figure E-3: Bus Route

SS Credit 4.2: Alternative Transportation – Bicycle Storage and Changing Rooms : 1 Point

- Providing bike racks within 200 yards of a building entrance which we will do
- Providing showers which we plan on putting in the locker rooms of the pool area
- Providing dedicated bike lanes to the end of the school property in 2 or more directions with no barriers which will be on all roadways on our school property

SS Credit 4.4: Alternative Transportation – Parking Capacity : 2 Points

Provide only the number of spaces required by local zoning and provide 0.05% preferred parking for carpools

- 68 spots x 0.05% = 3.4 – 4 spots

SS Credit 5.1: Site Development – Protect or Restore Habitat : 1 Point

For previously developed sites, include native PA plants on 20 % of the entire site, including the building footprint

- 307x574x.2= 35,000 SF for whole block
- 186x574x.2=22,000 SF exclude existing building area

MR Credit 5: Regional Materials : 1-2 Points

Use building products within 500 miles of the building site. Façade has already been estimated to be almost 10 % of building value, and Slenderwall is within the 500 mile range. Possible manufacturers for other components of the building include:

- High Steel in Lancaster, PA http://www.highsteel.com/
- Cemex near Pittsburgh http://www.cemexusa.com/
- Casework possibly from http://www.wood-metal.com/products/ (lots of LEED possibilities there)

With the addition of a few more materials, especially for finishes, 20% can be achieved. For casework, many other LEED capabilities exist, and a list of them can be seen on their website. Other points include VOC's and rapidly renewable resources.

IEQ Credit 3.1: Construction Indoor Air Quality Management Plan – During Construction : 1 Point

Must meet SMACNA IAQ Guidelines for buildings under construction, protect on-site and installed absorptive materials from moisture damage, replace all filtration media immediately prior to occupancy, prohibit smoking inside the building and within 25 feet of the building.

- To protect materials during construction, we plan to have storage containers on site. Also, our phased construction design will hopefully allow us to get portions of the building completed early to be used as material laydown areas that are protected from the elements.

Appendix G: Security and Building Logistics

Crime in Reading, PA

Reading, PA possesses a violent crime index far greater than both the state and national averages as can be seen in Figure G-1. Due to these statistics, our team felt the need to strongly emphasize security in the design of the elementary school.

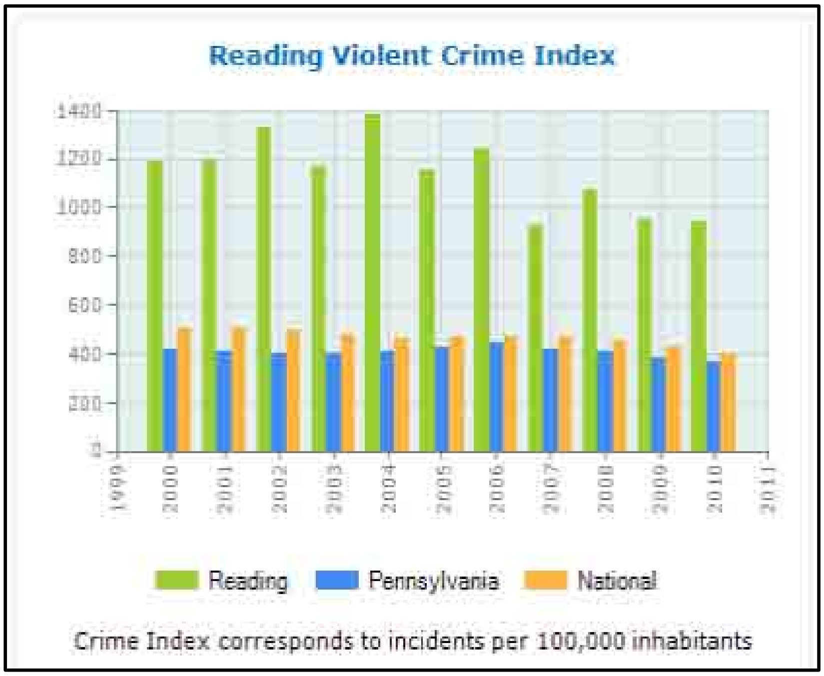


Figure G-1: Reading, PA Violent Crime Index

In addition to this, Reading annually experiences approximately 405 crimes per square mile, which is more than ten times the national average, as seen in Figure G-2.

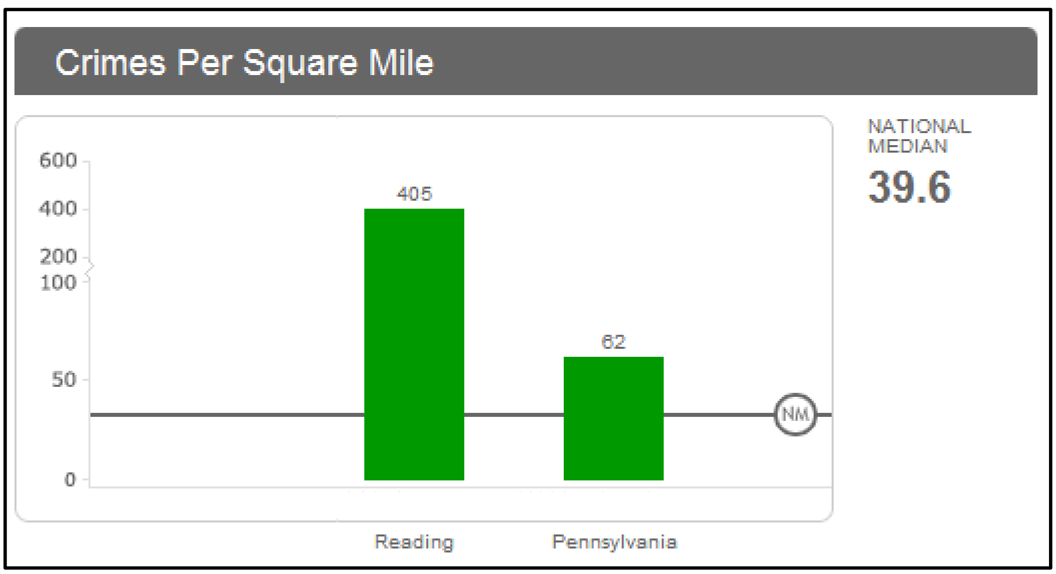


Figure G-2: Reading, PA Annual Crime Rate (Courtesy of Neighborhoodscout.com)

Appendix H: Code Analysis

Pennsylvania Code

§349.1 - States the following codes and professional guidelines must be followed and gives information about each one: AGA, NEC, NPC, ASHRAE, ANSI, IES, USSGSL, CEFP, ASTM, ASME, NFPA, SMACNA, EFL, OSHA, BOCA

§349.5 - Controls allowable square footage for elementary schools based on full-time equivalent students (FTE). 83,000 S.F. building yields a maximum of 1,573.

§349.6 - Building design code dictates the ratio of architectural space to scheduled space must not exceed 1.58. As seen in Table G-1, our proposed school yields a ratio of 1.53.

§349.11 - Aggregate Building Expenditure Standard (Act 34 of 1973) determines pupil capacity. As seen in Table G-2, our elementary school can accommodate 1304 pupils.

Table G-2: Elementary School Capacity

Elementary Buildings			
Size (SF)	Number	Points	Act 34 CPCTY
550-659	0	24	0
660-769	6	32	192
770-849	8	34	272
850+	24	35	840
		TOTAL	1304

Table G-1: Elementary School Space Ratio

Scheduled Area (Instructional Spaces)						TOTAL
Room	S.F.	Room	S.F.	Room	S.F.	
104	6141	202	613	302	133	
109	468	207	201	303	223	
110	251	208	1931	304	257	
111	159	209	407	309	201	
112	77	211	72	310	875	
113	295	212	1143	311	812	
119	353	213	536	312	792	
121	123	215	1545	313	801	
122	200	216	667	314	816	
123	80	217	687	316A	756	
132	1453	218	690	317	687	
134	765	219	294	318	687	
135	789	222	1108	319	690	
136	789	223	1022	324	1112	
140	1109	224	1022	325	1081	
141	1081	225	1022	326	1081	
142	1081	226	1022	327	1081	
143	1081	227	1041	328	1081	
144	1081	233	912	329	1101	
145	1114	234	991			
155	943	235	867			
159	892	236	847			
160	891					
	21216		18640		14267	**54,123**
Architectural Space						**83,000**
Ratio						**1.53**

IBC 2009

§ 303.1 Exception 4. Assembly areas that are accessory to Group E occupancies are not considered separate occupancies except when applying the assembly occupancy requirements of Chapter 11. A-4 Assembly uses intended for viewing of indoor sporting events and activities with spectator seating including, but not limited to arenas, skating rinks, swimming pools, and tennis courts.

§ 305.1 Educational Group E. Educational Group E occupancy includes, among others, the use of a building or structure, or a portion thereof, by six or more persons at any one time for educational purposes through the 12th grade.

§ 1004.7 Fixed Seating. For areas having fixed seating and *aisles* the *occupant load* shall be determined by the number of fixed seats installed therein. The *occupant load* for areas in which fixed seating is not installed, such as waiting spaces and *wheel-chair* spaces, shall be determined in accordance with Section 1004.1.1 and added to the number of fixed seats. For areas having fixed seating without dividing arms, the *occupant load* shall not be less than the number of seats based on one person for each 18 inches of seating length. Table G-3 shows maximum occupancies for various areas in the elementary school.

Table G-3: Elementary School Occupancies

Maximum Occupancies by Area (by Table 1004.1.1)	
Area	**Occupancy**
Average Classroom	45
Multipurpose	877
Community Room	160
Library	38
Pool	54
Pool Deck	180
Pool Seating	120
Locker Rooms	20

§ 1005.1 Minimum Egress Width. The total width of means of egress in inches shall not be less than the total *occupant load* served by the *means of egress* multiplied by 0.3 inches per occupant for stairways and by 0.2 inches per occupant for other egress components. Multiple *means of egress* shall be sized such that the loss of one shall not reduce the available capacity to less than 50% of the required capacity.

(234 occupants in pool area)/2 exits x 0.3 inches = 35 inch wide stairways minimum
(234 occupants in pool area)/1.5 exits x 0.3 inches = 47 inch wide stairways needed in the case that one is inaccessible. Increase to 48 inches because of Section 1007.3: Stairways.

(234 occupants in pool area)/2 exits x 0.2 inches = 24 inches wide for other parts of egress path
(234 occupants in pool area)/1.5 exits x 0.2 inches = 32 inches wide for other parts of egress path in the case that an exit is inaccessible.

§ 1007.5 Platform lifts - Shall not serve as a part of an *accessible means of egress*.

§ 1007.5.1 Openness. Platform lifts on an *accessible means of egress* shall not be installed in a fully enclosed hoistway.

§ 1007.6.1 Size. Each *area of refuge* shall be sized to accommodate one *wheelchair space* of 30 inches by 48 inches for each 200 occupants, based on the *occupant load of the area of refuge* and areas served by the *area of refuge.*

Table G-4: Fire-Resistance Rating Requirements

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	Ad	B	Ad	B	HT	Ad	B
Primary structural frame[g] (see Section 202)	3[a]	2[a]	1	0	1	0	HT	1	0
Bearing walls Exterior[f, g] Interior	 3 3[a]	 2 2[a]	 1 1	 0 0	 2 1	 2 0	 2 1/HT	 1 1	 0 0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[e]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and secondary members (see Section 202)	$1\frac{1}{2}$[b]	1[b, c]	1[b, c]	0[c]	1[b, c]	0	HT	1[b, c]	0

Appendix I: References

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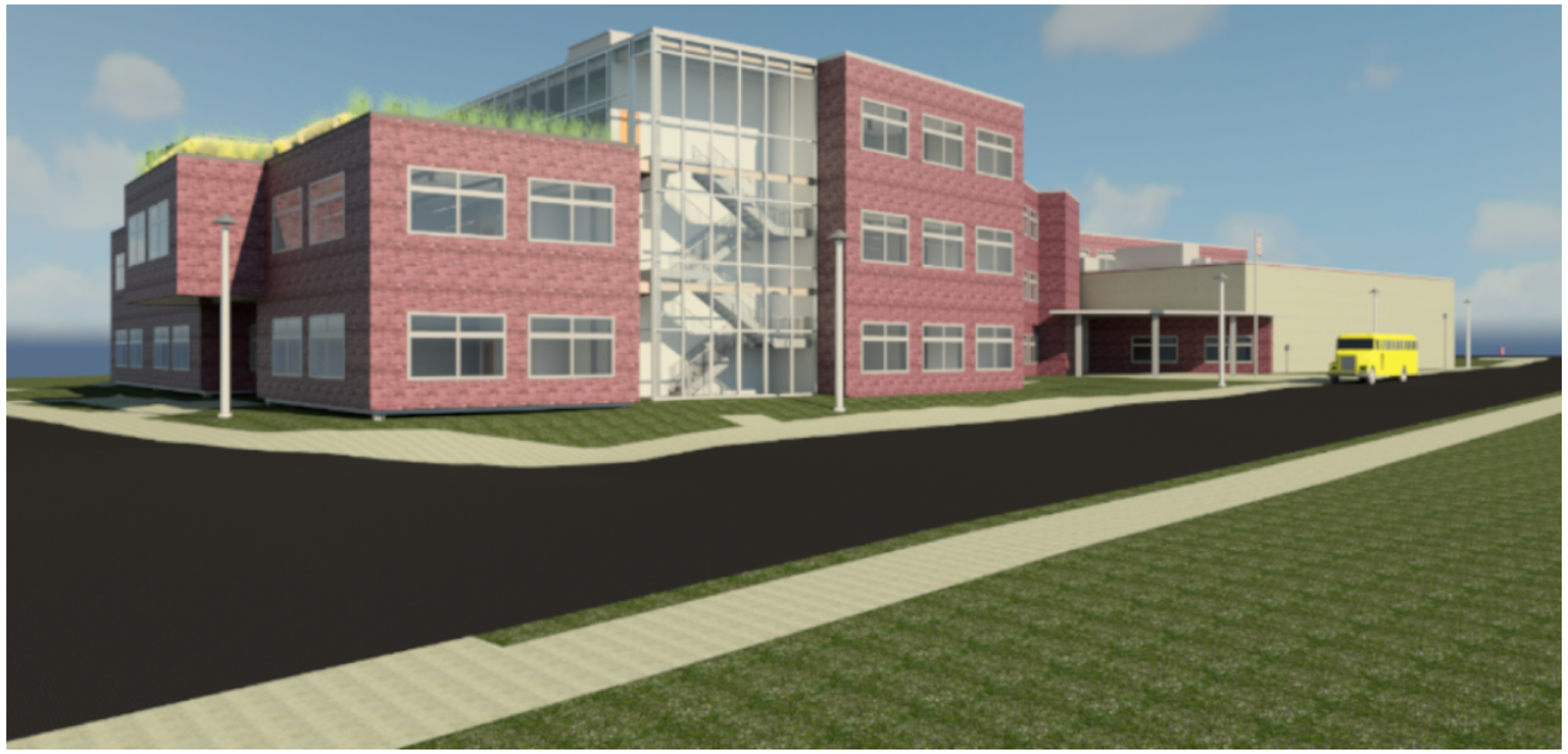
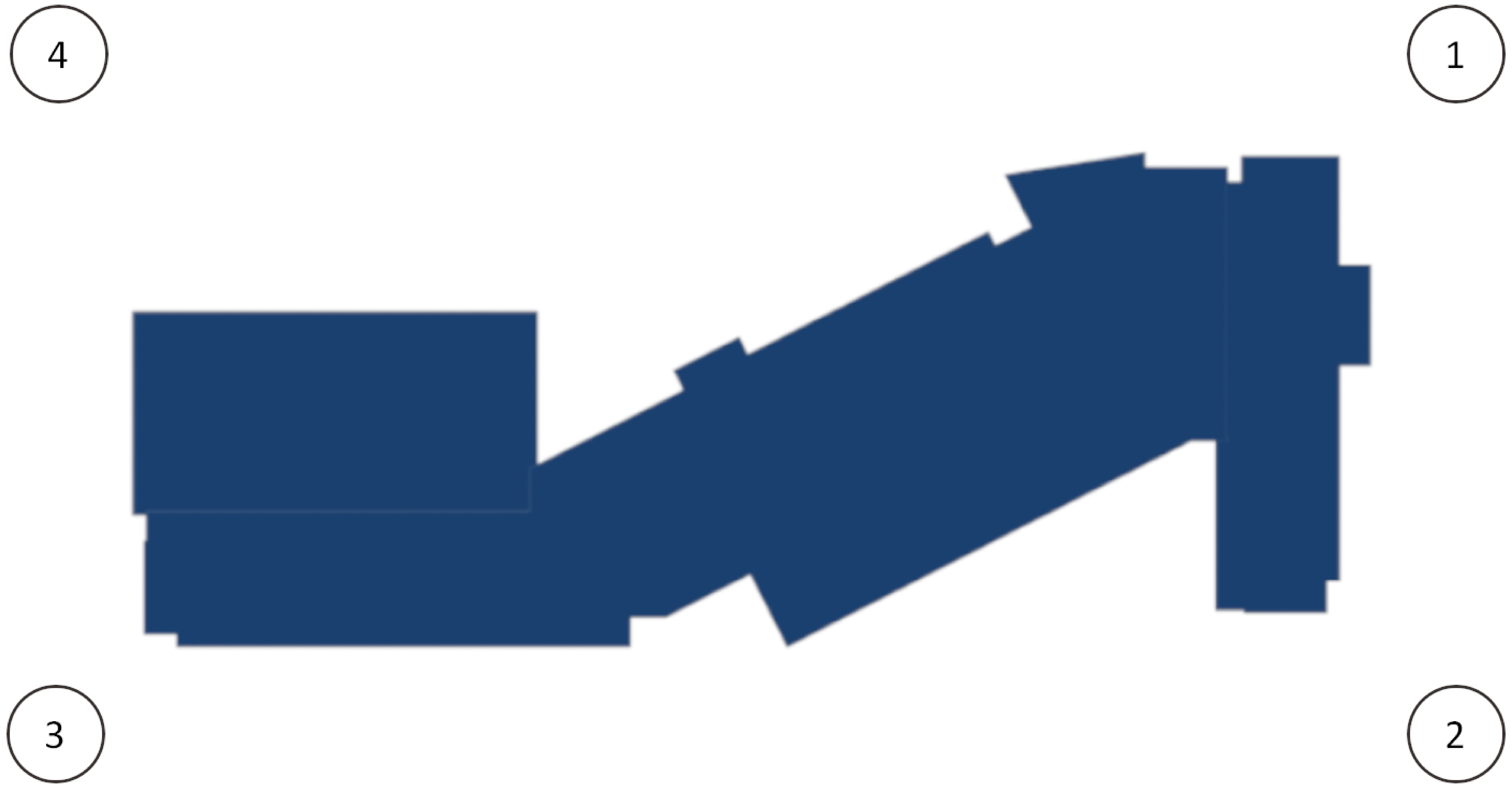
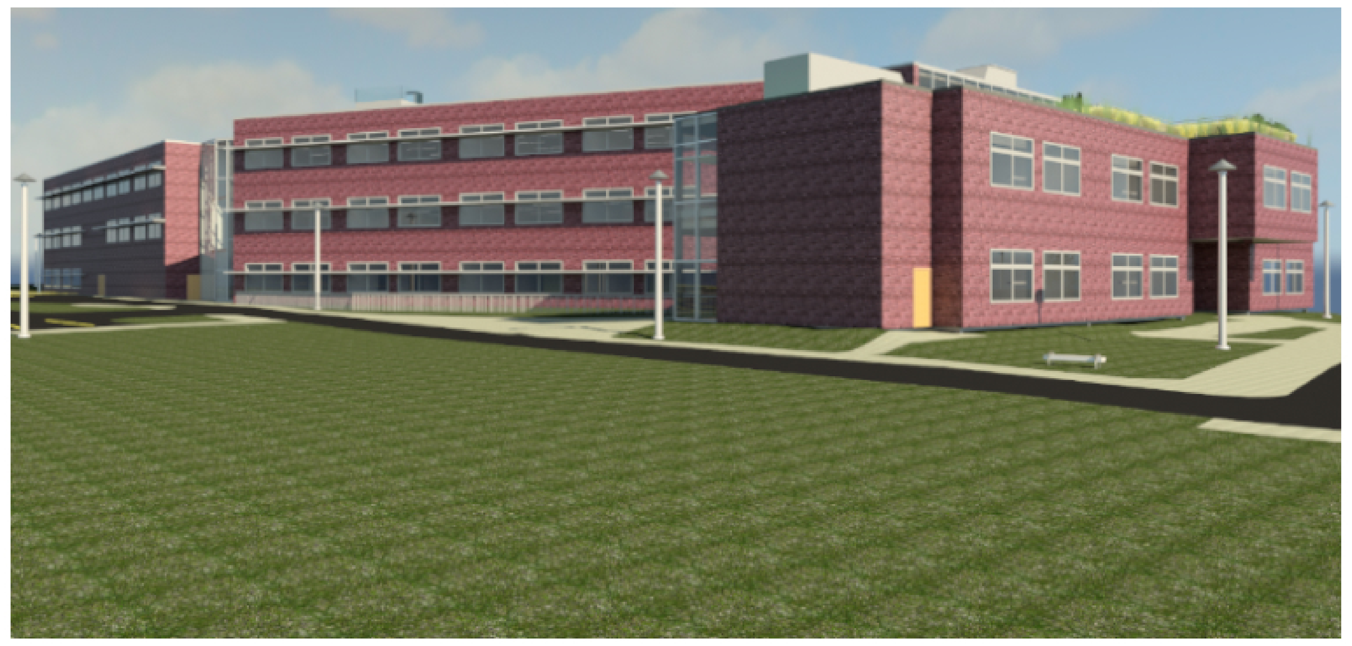


1: Northeast exterior perspective

Looking toward Reading Elementary School from its northeast corner, one can see the green roof above the east wing classrooms, as wel as the glazing-encased staircase that reaches up to the third floor classrooms. Looking further down Park Stret, the school's main covered entrance can be seen against the eastern wall of one of the school's most unique spaces, the multipurpose room/shelter.





2: Southeast exterior perspective

Seen above is the east classroom wing with green roof above, as well as the main classroom wing.

3: Southwest exterior perspective

The exterior lightshelves on the classroom windows can be easily viewed from the southwest corner of the building.

4: Northeast exterior perspective

AEI TEAM
10-2013

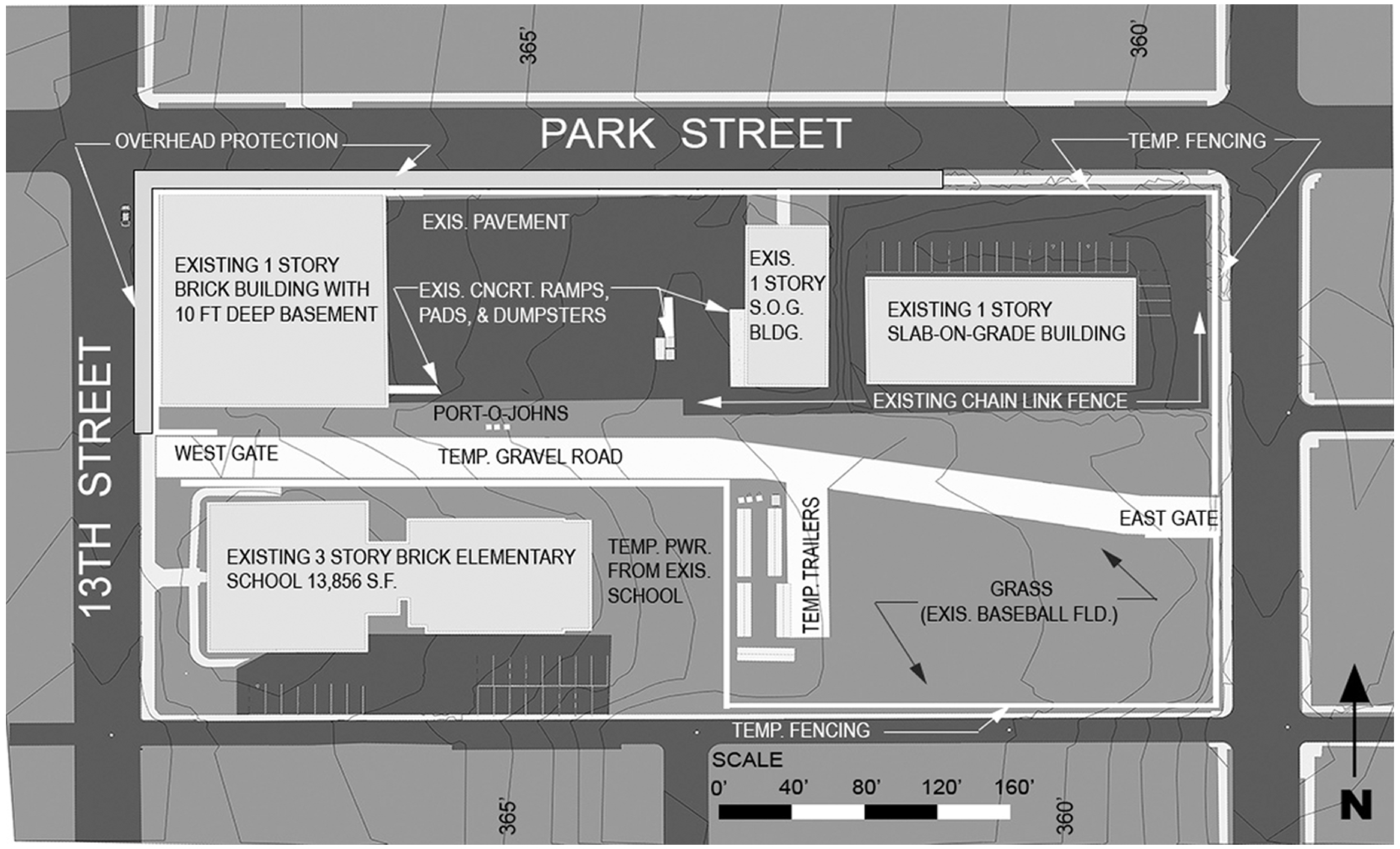
READING ELEMENTARY SCHOOL

EXTERIOR PERSPECTIVES

Date 02.22.2013

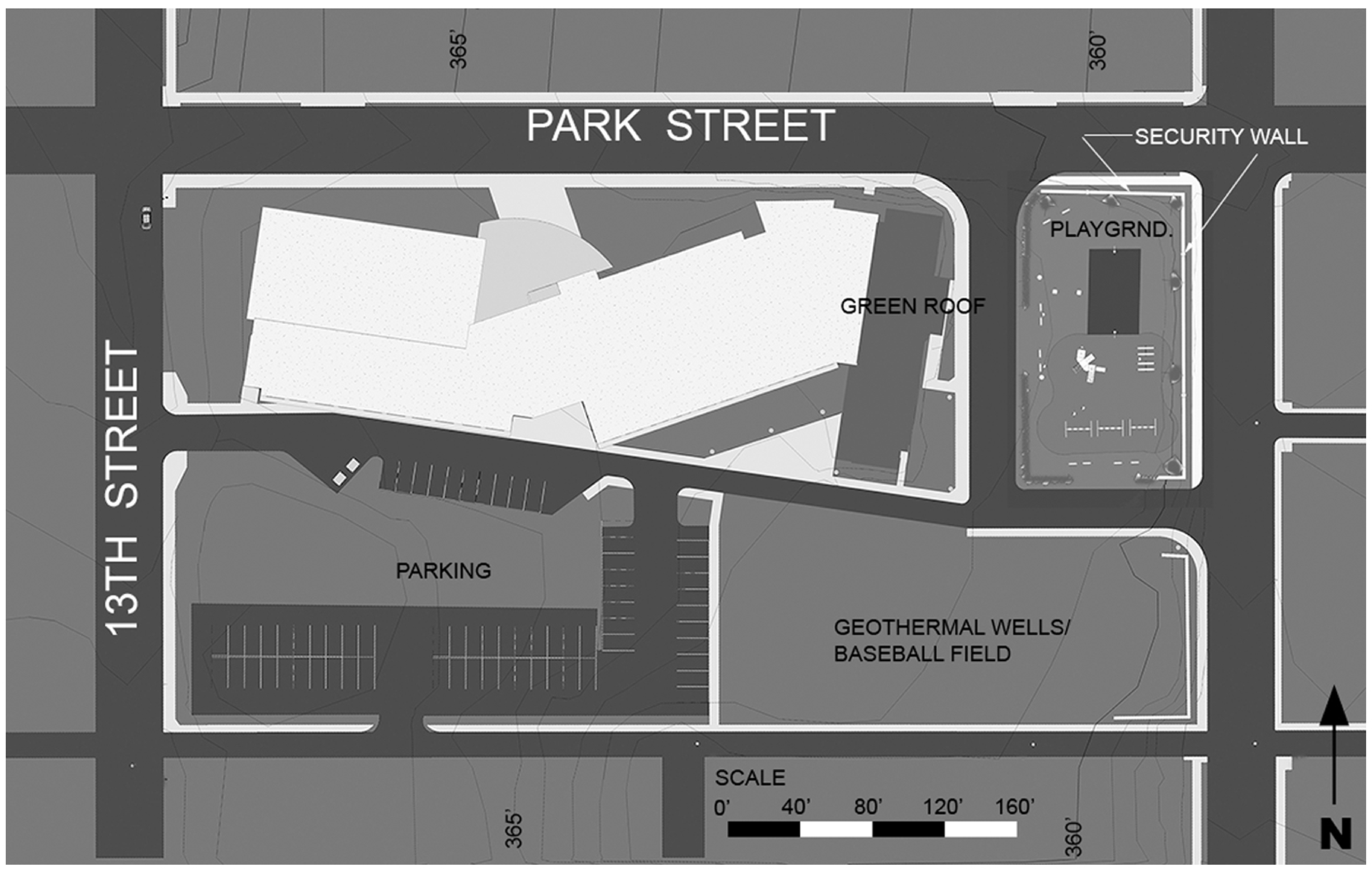
I-001

Scale



Existing Conditions

Our design team suggests demolishing the existing 3-story elementary school and relocating the parking lot to this location, where some parking spaces already exist. Adding to the already established parking lot will cut cost and schedule for the project. This more centrally located parking lot promotes security by reducing travel time between the building and vehicle. The land gained from the relocation of the parking lot can be used as a community playground for both school students and the children of Reading, PA. Erecting a security wall around the perimeter of the playground will prevent line of sight to the children from the surrounding streets.



Building Turnover

The addition of the community playground and its surrounding wall combined with the relocation of the parking lot enhance the usability and safety of the parking lot. The proposed site plan effectively utilizes the land surrounding Reading Elementary School while accomplishing our team's design goals of prioritizing security and enhancing the sense of community.

AEI TEAM
10-2013

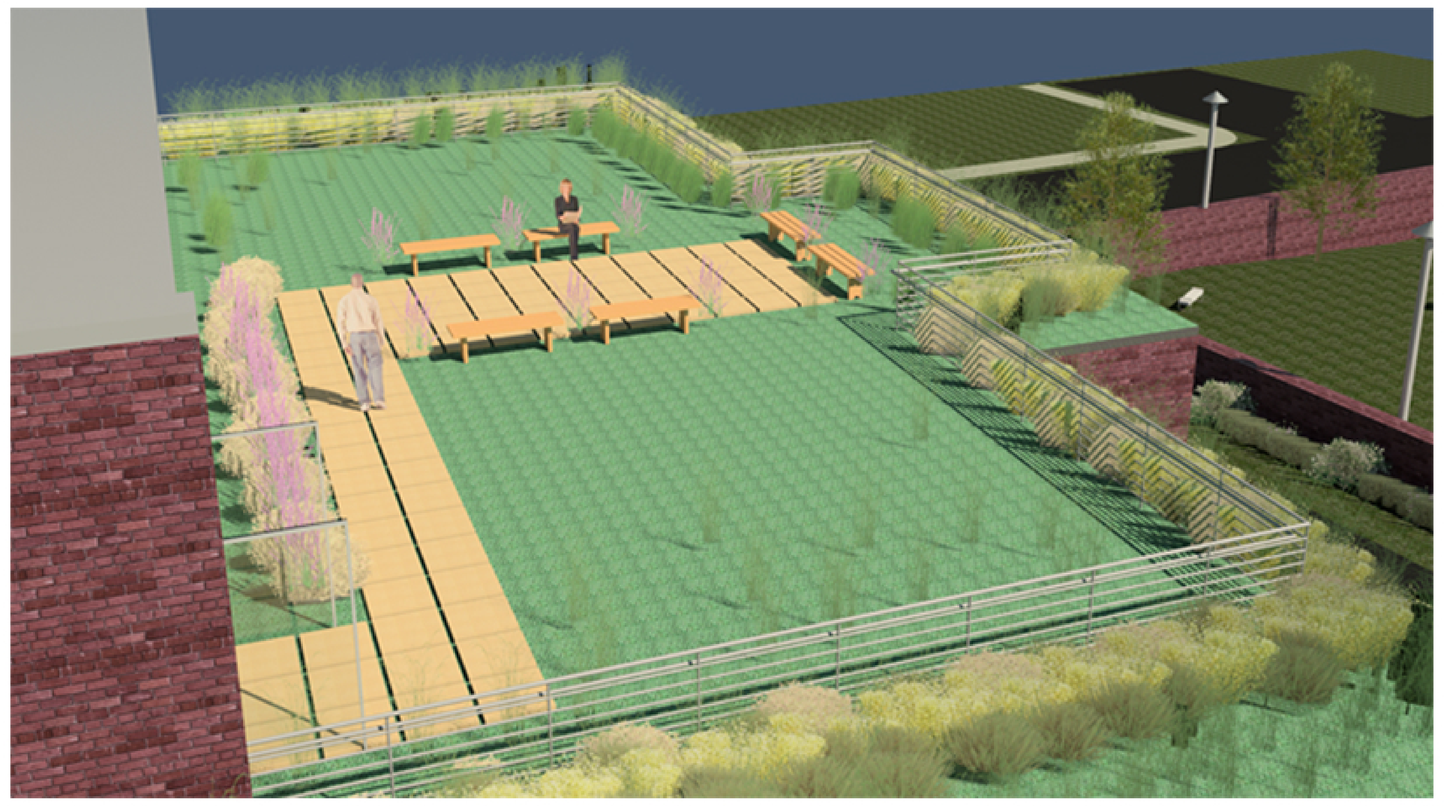
READING
ELEMENTARY SCHOOL

SITE PLAN

Date 02.22.2013

I-002

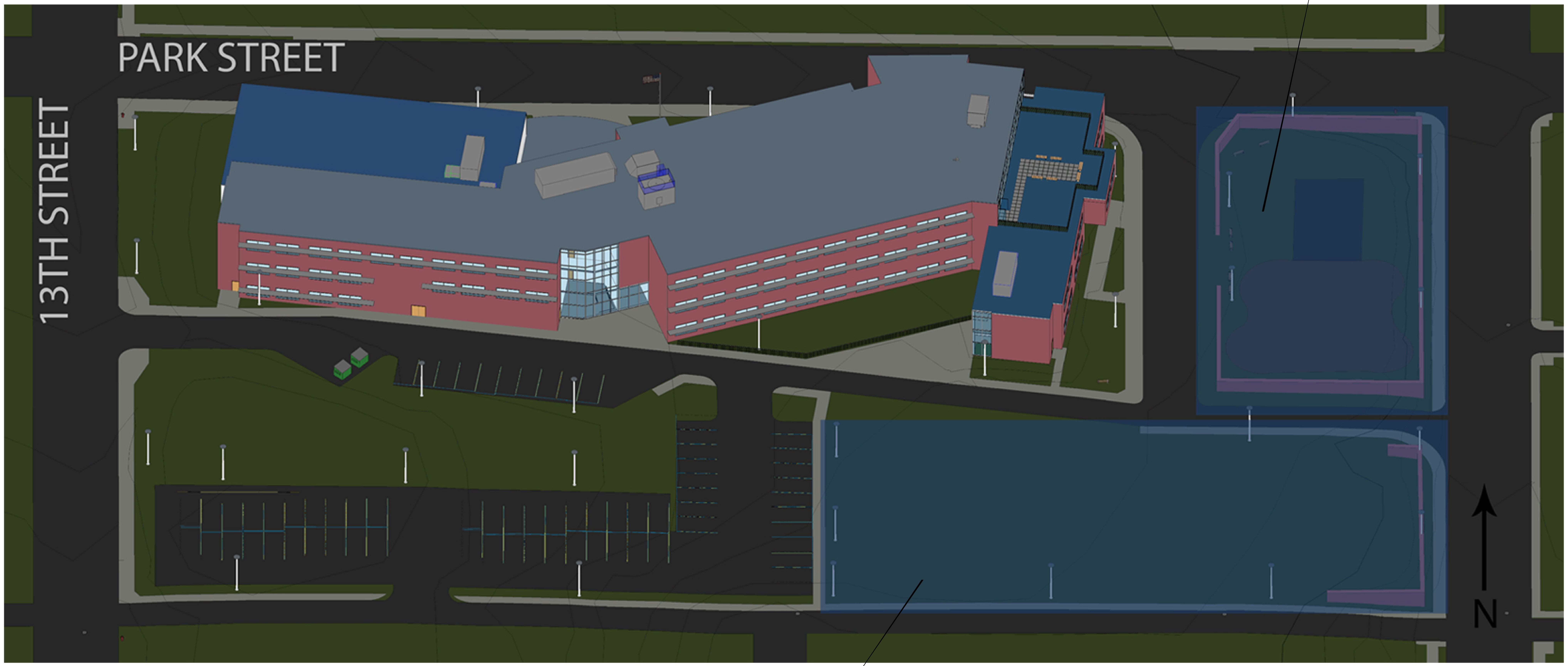
Scale



Green Roof/Outdoor Classroom

Community Playground

Multipurpose Room/Shelter



Baseball Field/Geothermal

The site includes 20 geothermal ground wells drilled to a depth of 250 feet. The sports field offers a superb location to drill wells. This will allow for any maintenance or future system expansion to occur without disturbing site parking. Due to uncertainties in the ground heat transfer capacity, we have elected to be more conservative with our ground well design. This allows the school board to test the system with a lower initial cost. After performance is verified the system can be doubled in size to further offset heating/cooling energy demand.

AEI TEAM
10-2013

READING ELEMENTARY SCHOOL

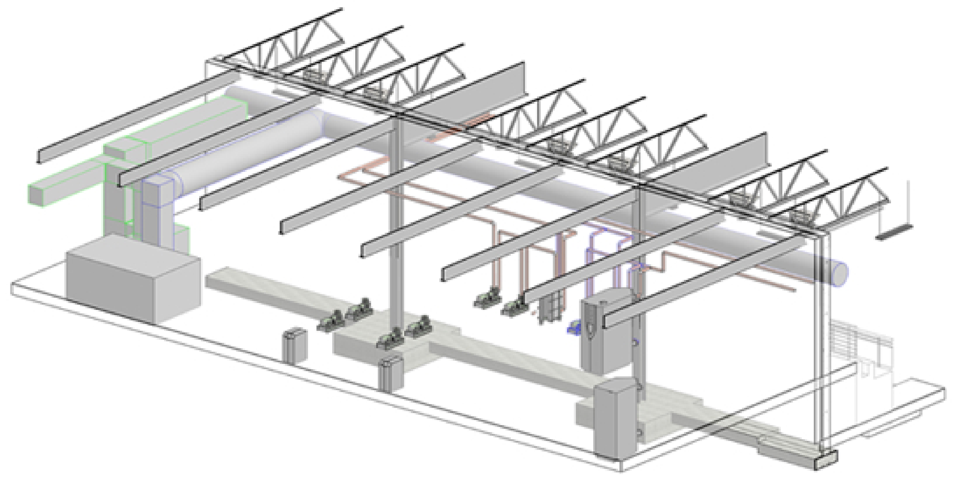
3-D SITE PLAN

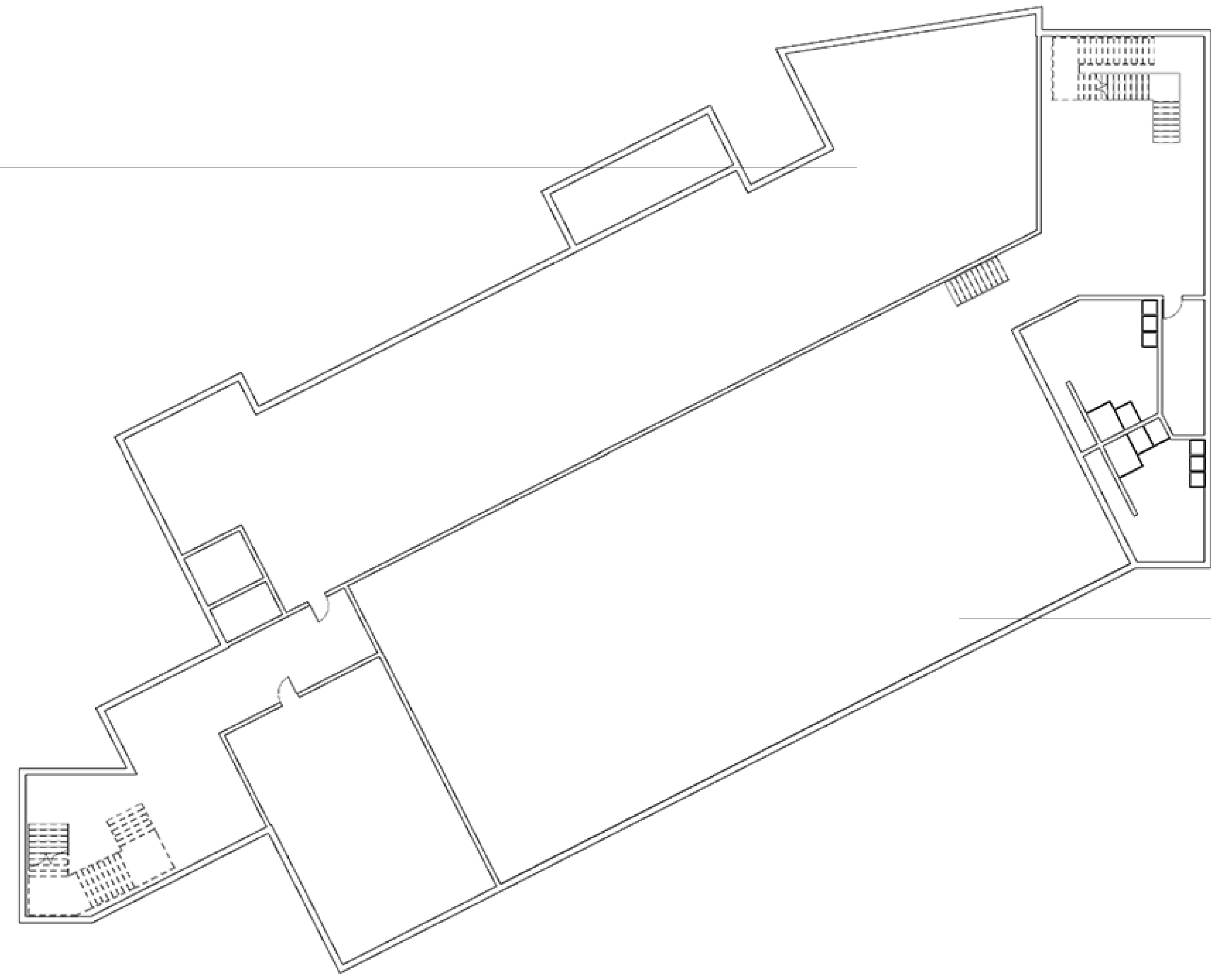
Date 02.22.2013

I-003

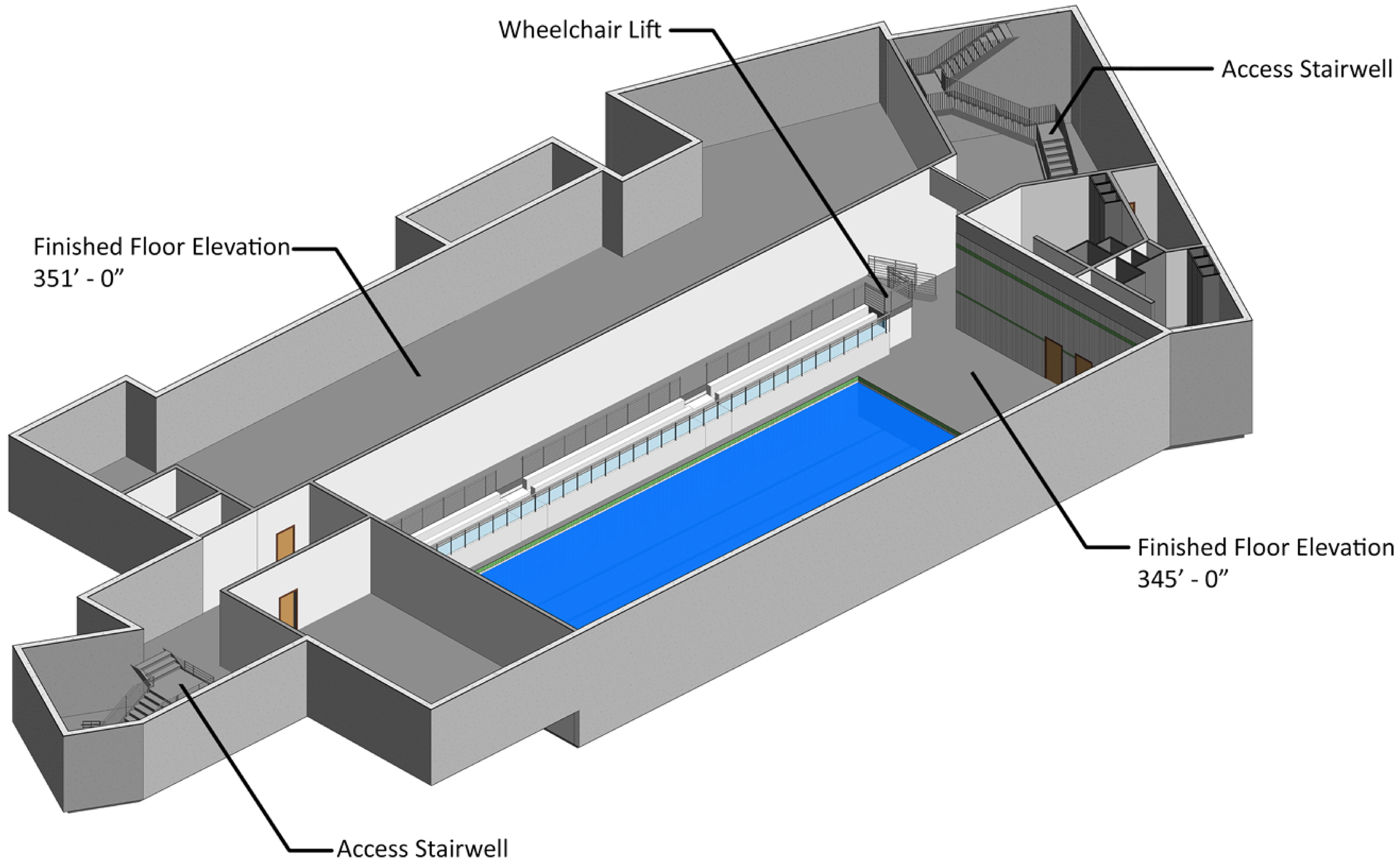
Scale

Mechanical Room

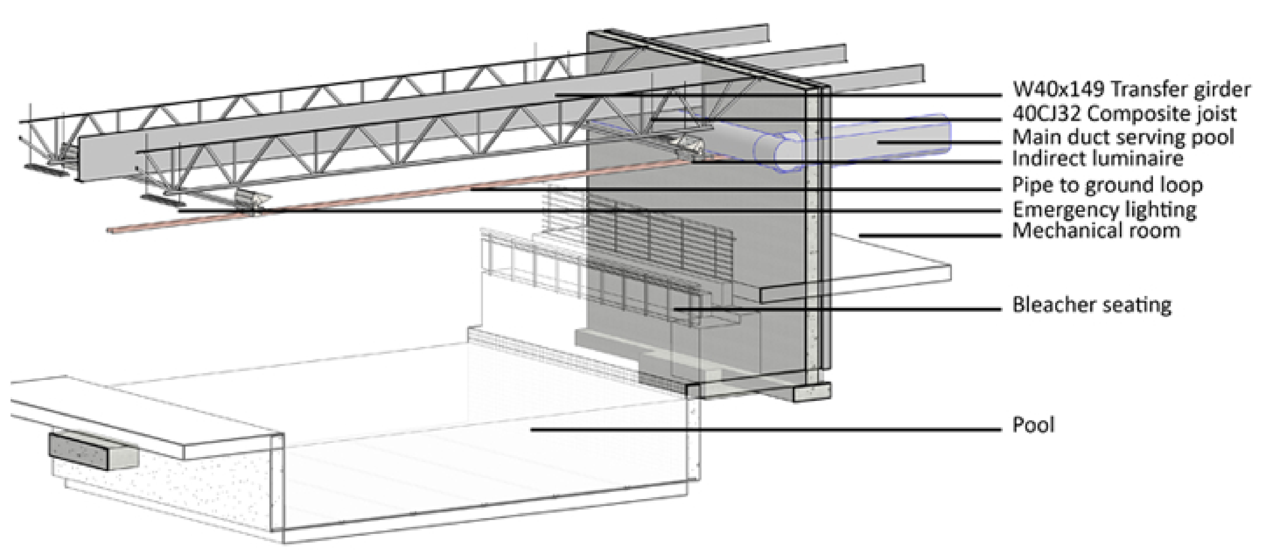




The mechanical room houses equipment that serves the building and utility connections. Specifically, it contains pumps, heat exchangers, boilers, and pool air-handling unit. The heat exchanger located within the mechanical room is connected with the geothermal loop and helps to conserve energy.



Community Pool



Our design team decided to include an indoor pool in the design. The indoor pool would see the maximum use because of Reading, Pennsylvania's climate. This pool can be used for recreational events for the community. If the school board decides not to proceed with the pool, this space can be excavated and serve as a future fitness center addition.

AEI TEAM
10-2013

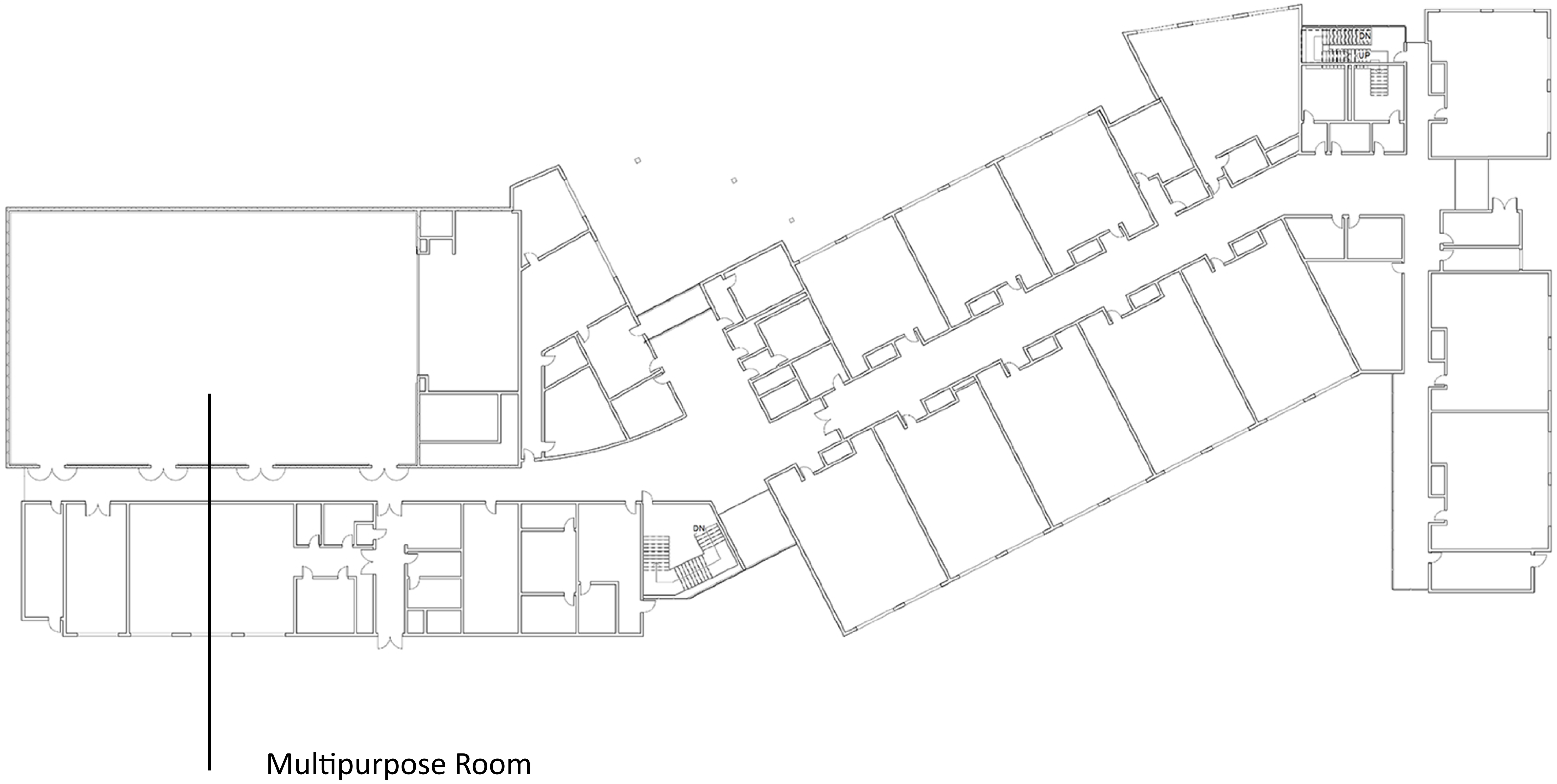
READING ELEMENTARY SCHOOL

BASEMENT

Date 02.22.2013

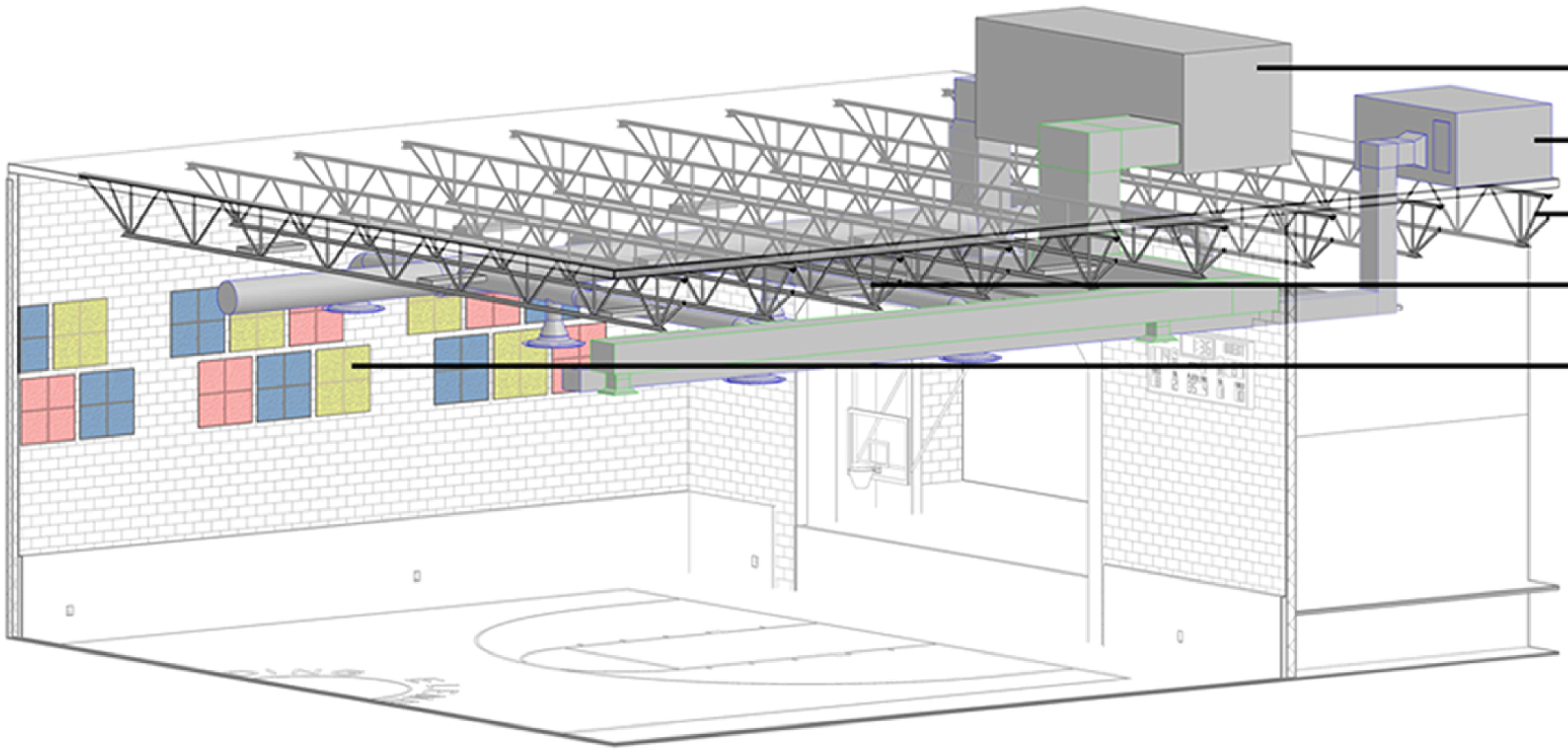
I-100

Scale 1/16" = 1'-0"



Multipurpose Room Rendering

This image displays the interior of the multipurpose room, highlighting the structural, mechanical, and lighting systems, as well as the acoustical treatment on the wall.



Multipurpose Room Systems Integration

The multipurpose room is unique in that it also serves as a shelter facility for the school and community. Because of this, all of the engineering systems as shown above are designed to operate as standalone systems from the rest of the building. Coordination between disciplines coupled with 3-D modeling using Revit technology helped to ensure an effective layout with minimal clashes throughout design.

AEI TEAM
10-2013

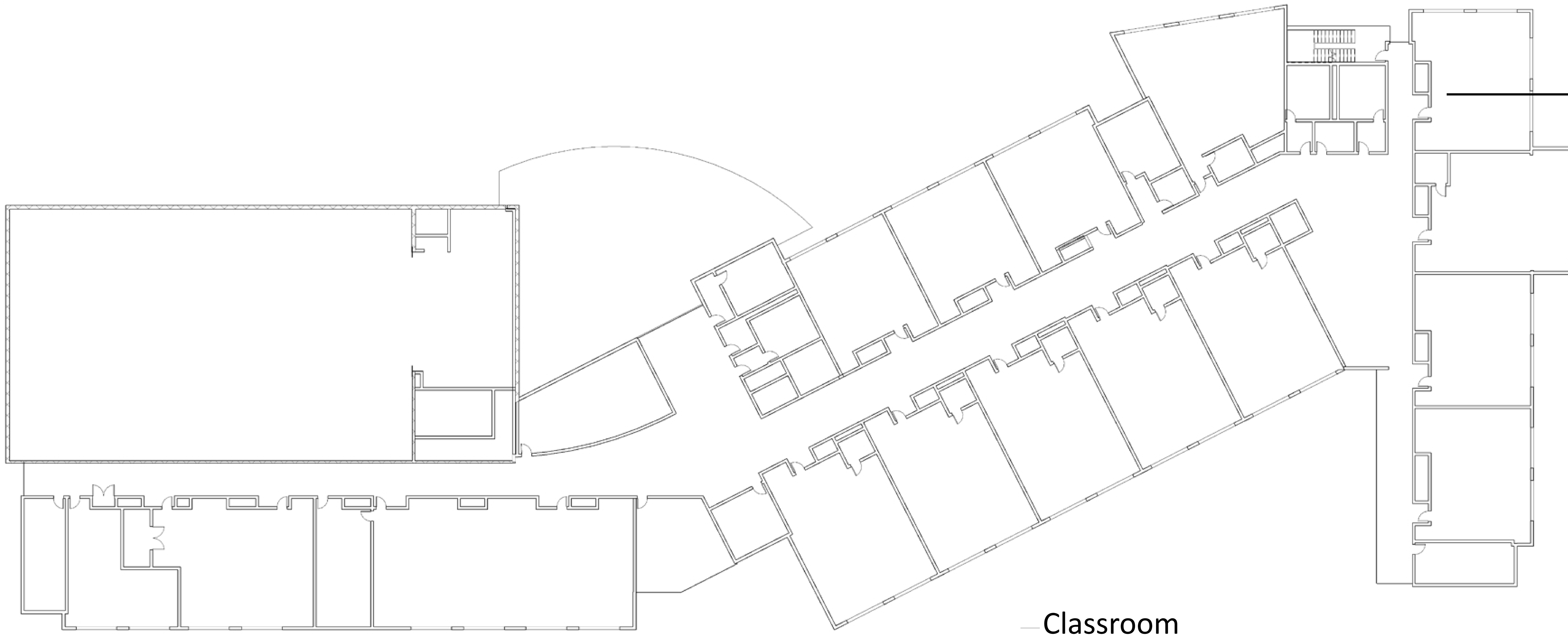
READING ELEMENTARY SCHOOL

FIRST FLOOR

Date 02.22.2013

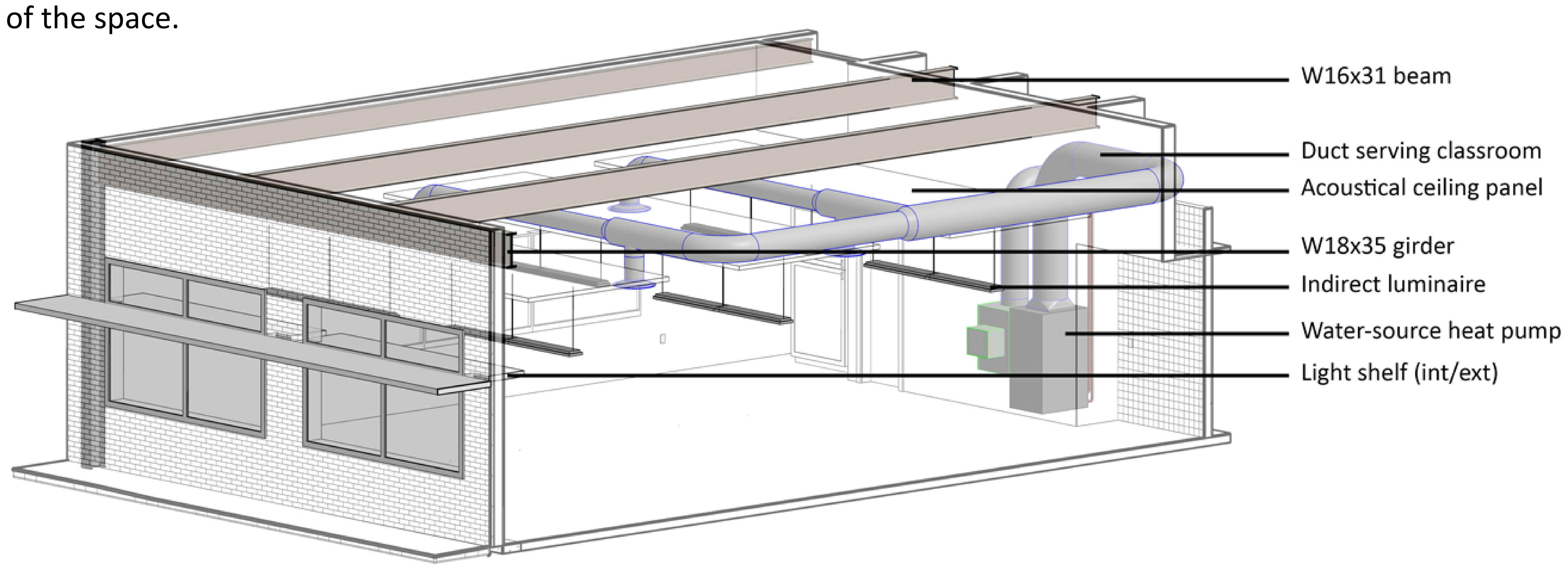
I-101

Scale 1/16" = 1'-0"



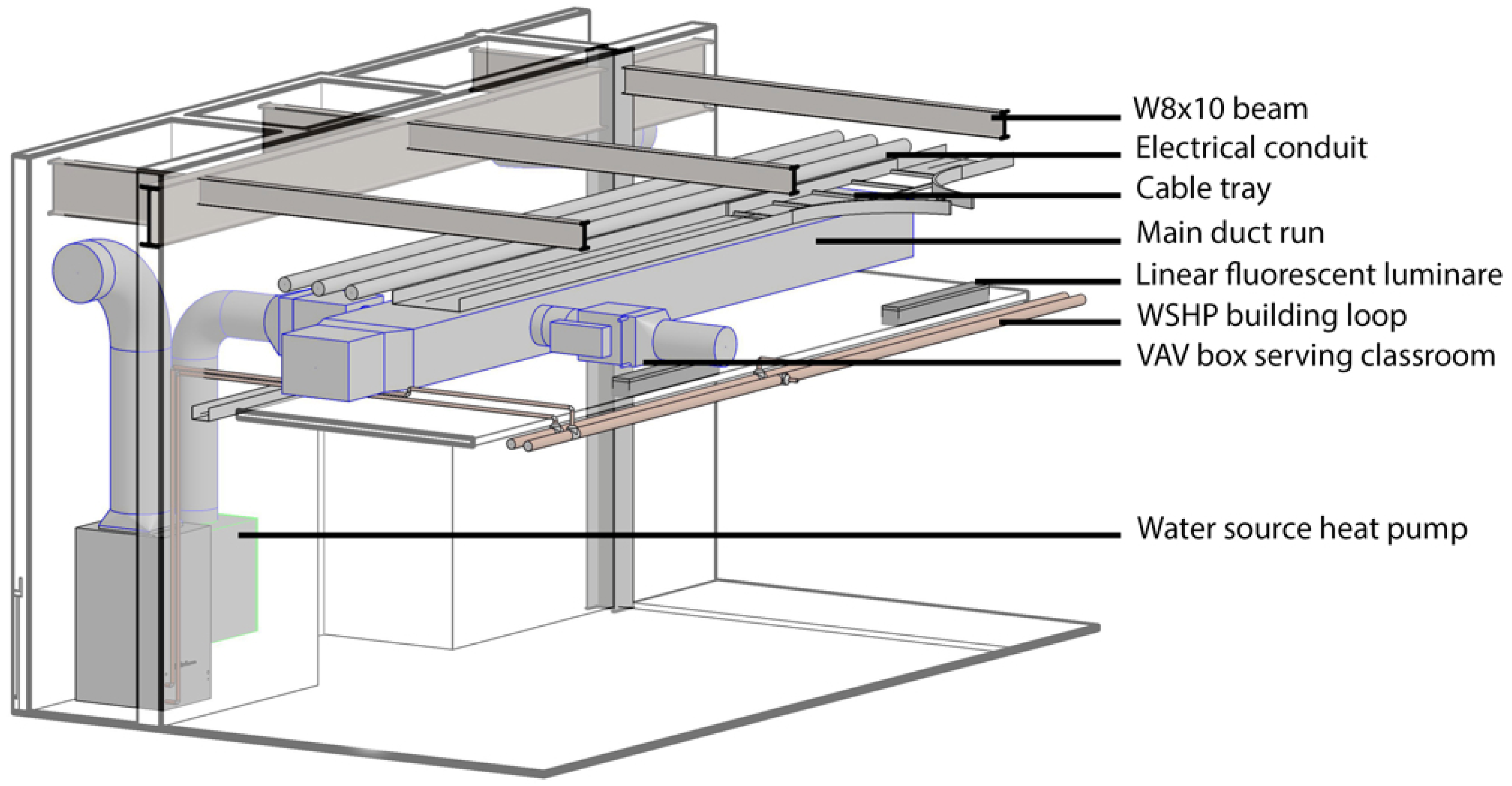
Typical Classroom Interior Rendering

Classrooms in Reading Elementary School were designed to achieve the goal of using the building as a learning tool. This is important for educating children about building systems and how they function, as well as obtaining LEED credits. Mechanical, structural, and lighting/electrical systems are all visibile from the desks in the classroom, and are covered in select locations by suspended panels to enhance the acoustic performance of the space.



Corridor Rendering

The corridors throughout Reading Elementary School adhere to our goal of using the building as a teaching tool, leaving portions of the building systems exposed, while covering the majority to minimize background noise levels.



AEI TEAM
10-2013

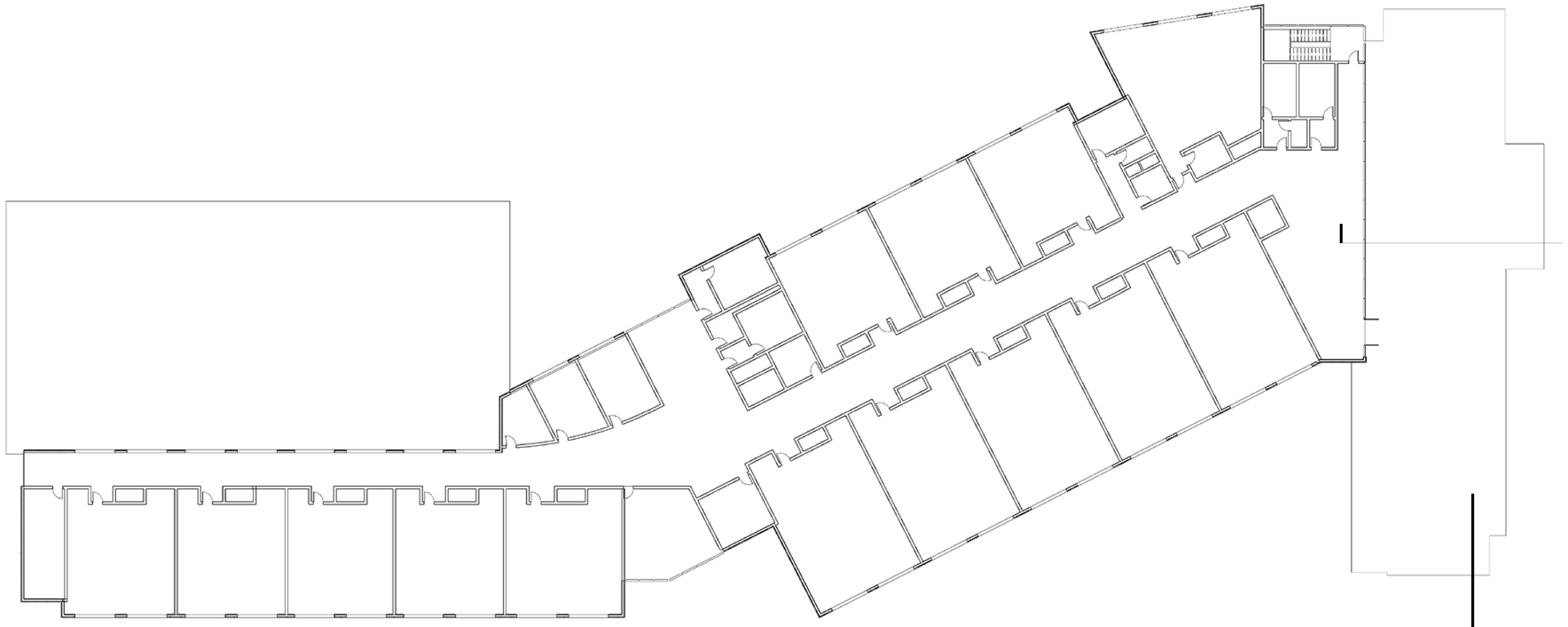
READING ELEMENTARY SCHOOL

SECOND FLOOR

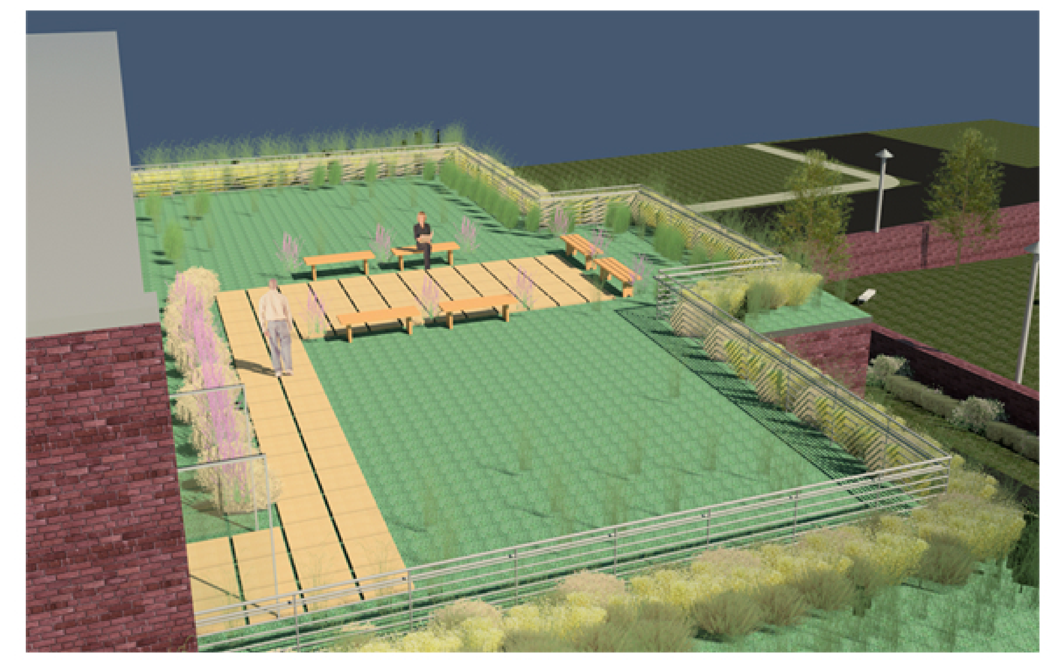
Date 02.22.2013

I-102

Scale 1/16" = 1'-0"

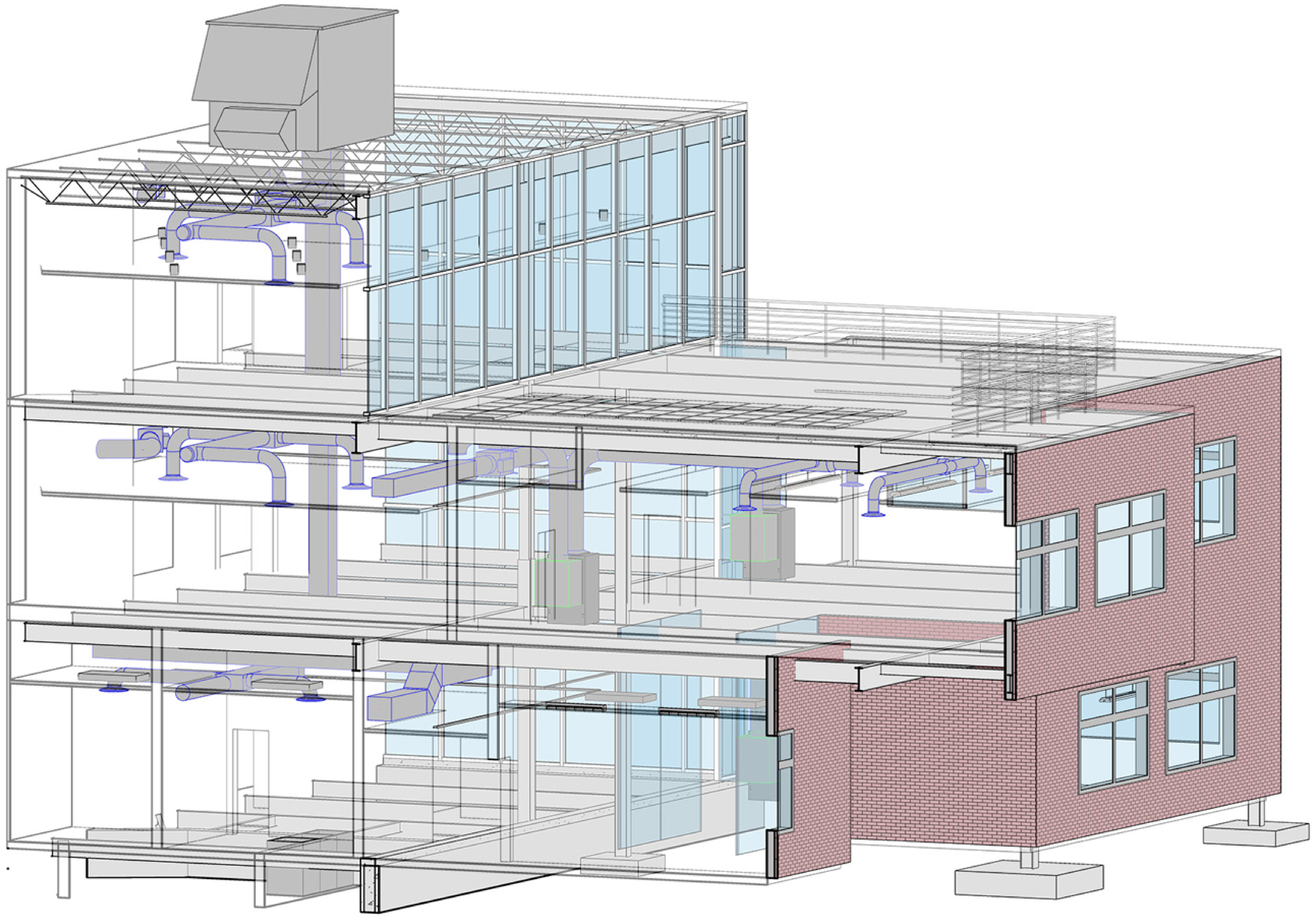


East Wing Building Section



Green Roof

The green roof serves as both a learning tool for the students as well as a visually pleasing space from both the exterior and interior of the building.



East Wing Building Section

The east wing building section displays the relationship between the east wing classrooms, the green roof, and their respective structural, mechanical and electrical systems. The mechanical system is served by a rooftop air handling unit with a shaft running vertically downwards to the three floors. Structurally, the green roof is supported by a cantilever providing an interesting experience to both students and teachers. Daylight is integrated into our team's design through the use of the curtain wall on the east wall of the large group instruction space.

Large Group Instruction view to Green Roof

This flexible learning space allows views to the top of the green roof, providing a unique learning opportunity for the students.

AEI TEAM
10-2013

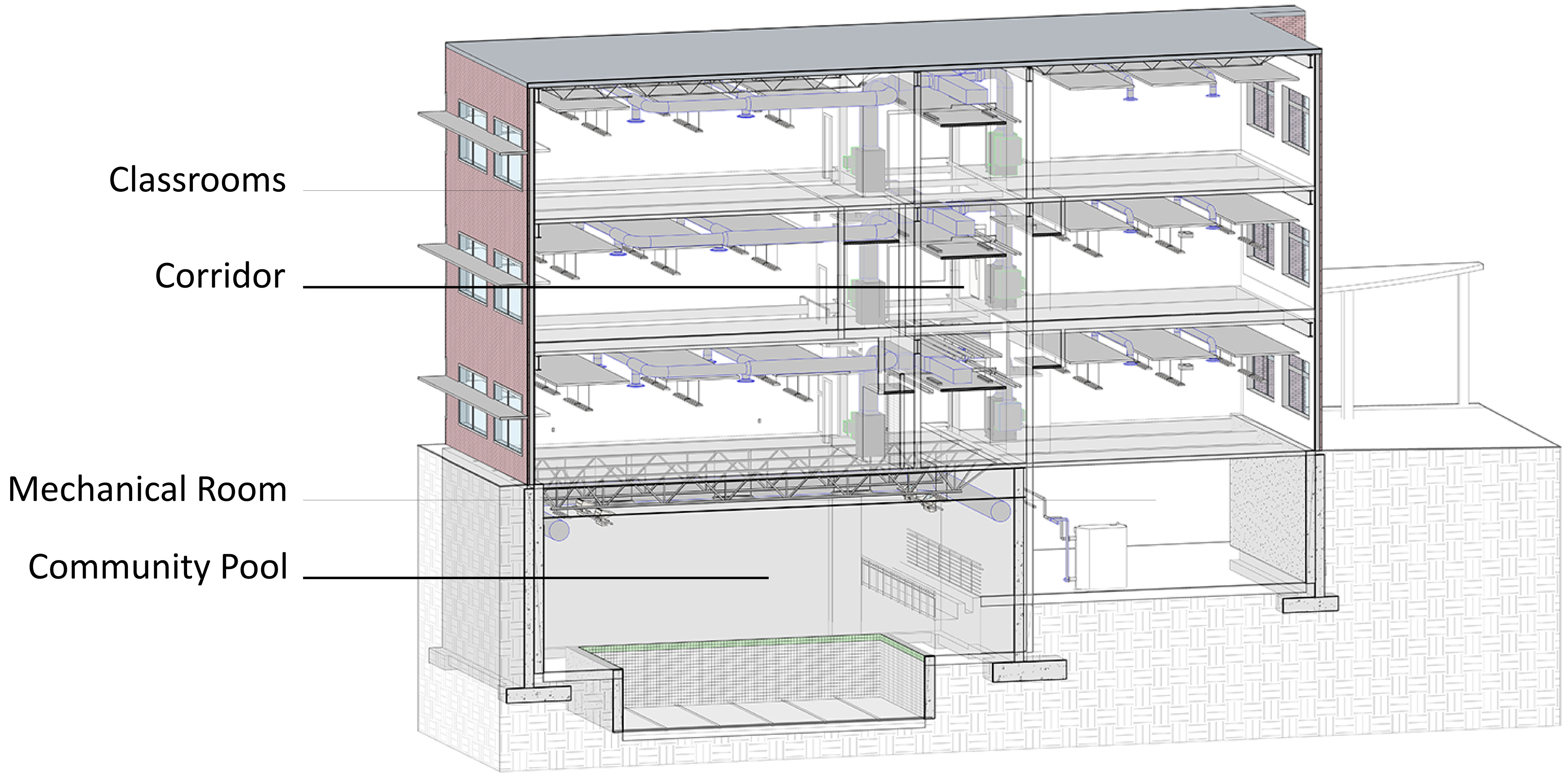
READING ELEMENTARY SCHOOL

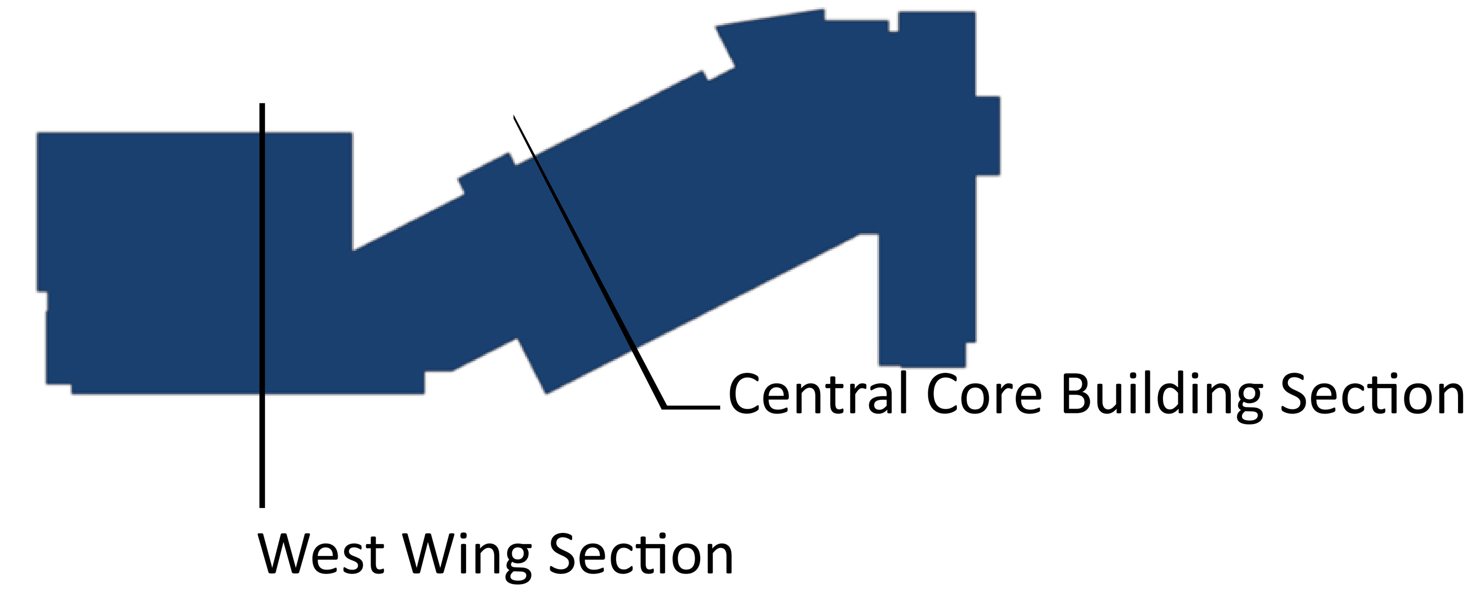
THIRD FLOOR

Date 02.22.2013

I-103

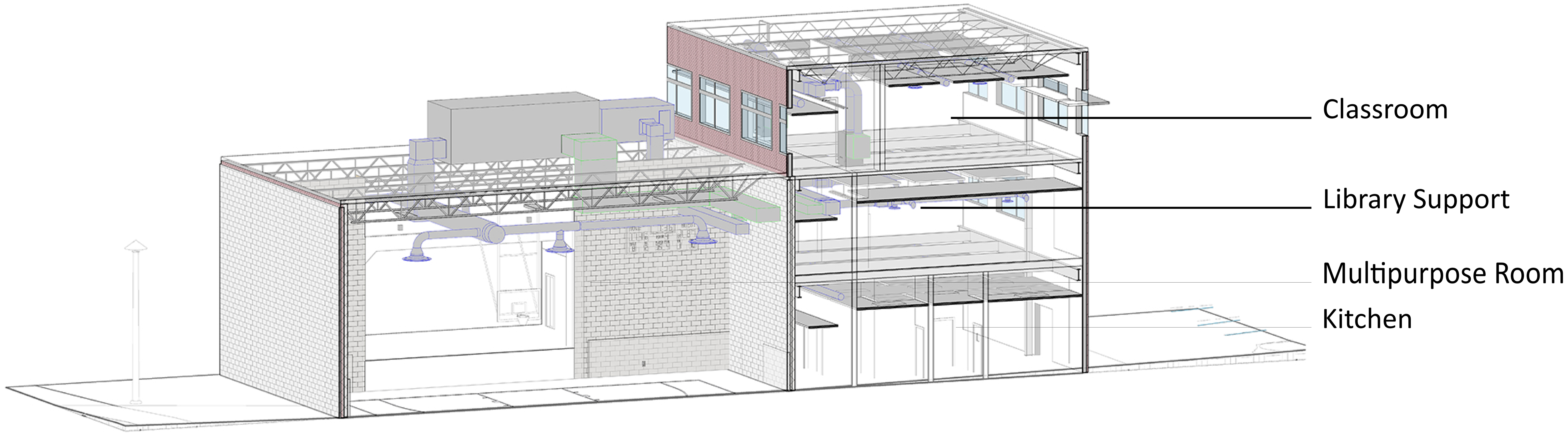
Scale 1/16" = 1'-0"





Central Core Building Section

The central core building section depicts the relationship between the pool, classrooms, and mechanical room. Each corridor houses main mechanical, electrical, and telecomm runs connected to the main mechanical and electrical rooms located on the basement level. These services run vertically though the chase that is centrally located by the elevator shaft. Also, it is important to note that the pool elevation is 6’-0” lower than the rest of the basement.



West Wing Section

The west wing section depicts the relationship between the multipurpose room, kitchen, library, and classroom. The mechanical equipment serving the multipurpose room and kitchen is located on the roof of the multipurpose room as seen in this section. This equipment was placed directly above the stage area where structural members can be increased to handle addition loads.

AEI TEAM
10-2013

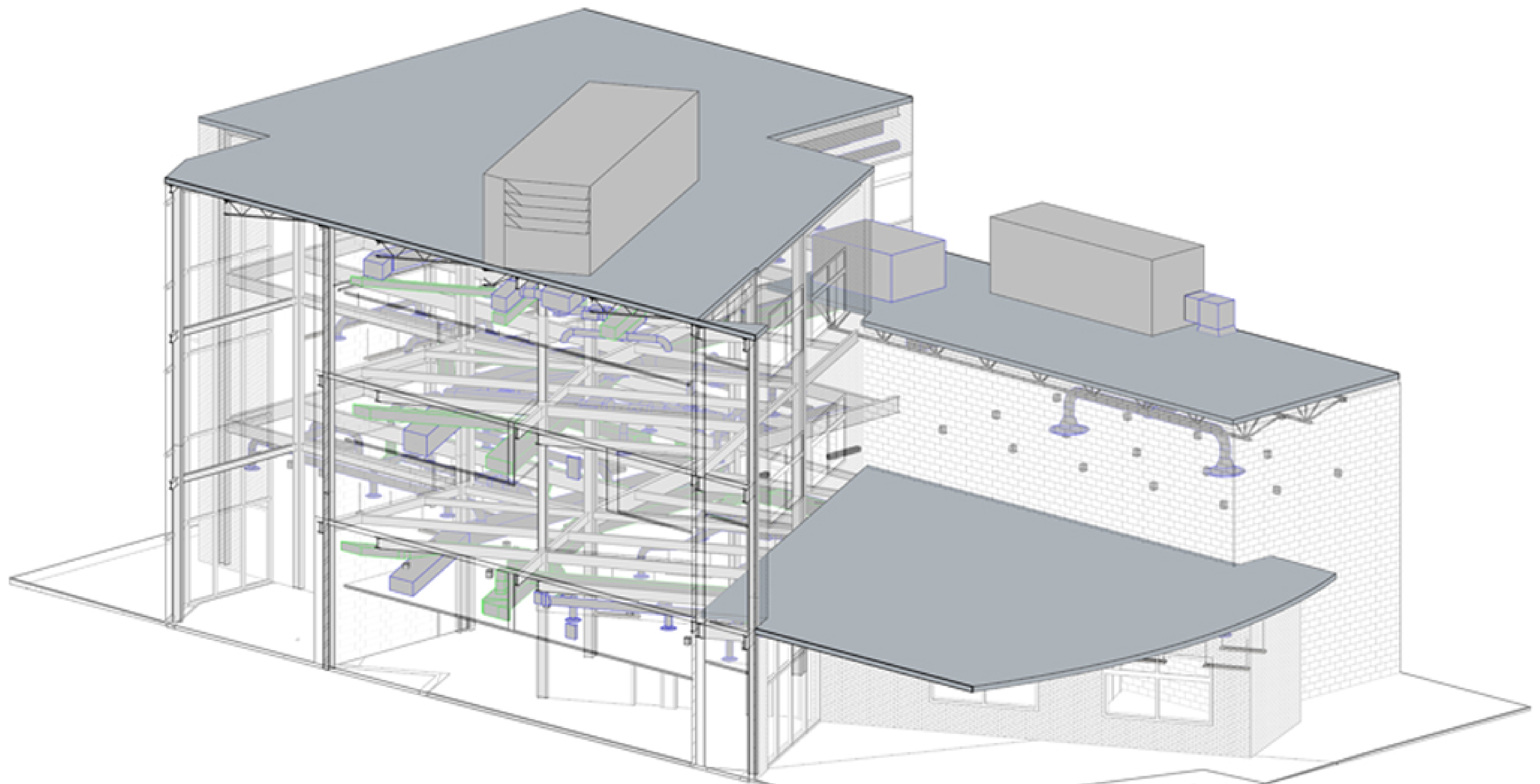
READING
ELEMENTARY SCHOOL

BUILDING SECTIONS

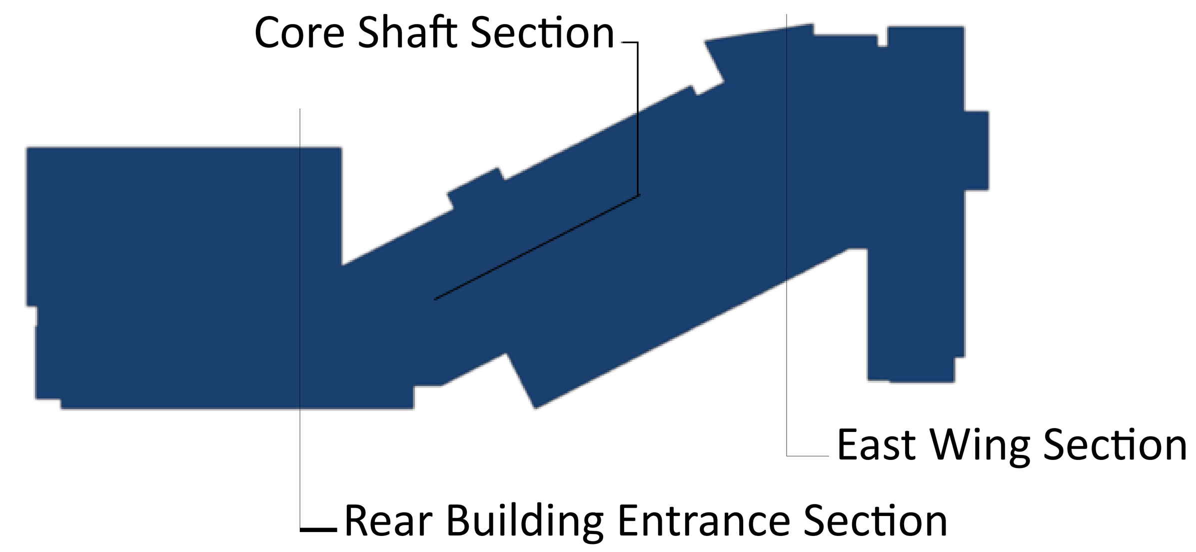
Date 02.22.2013

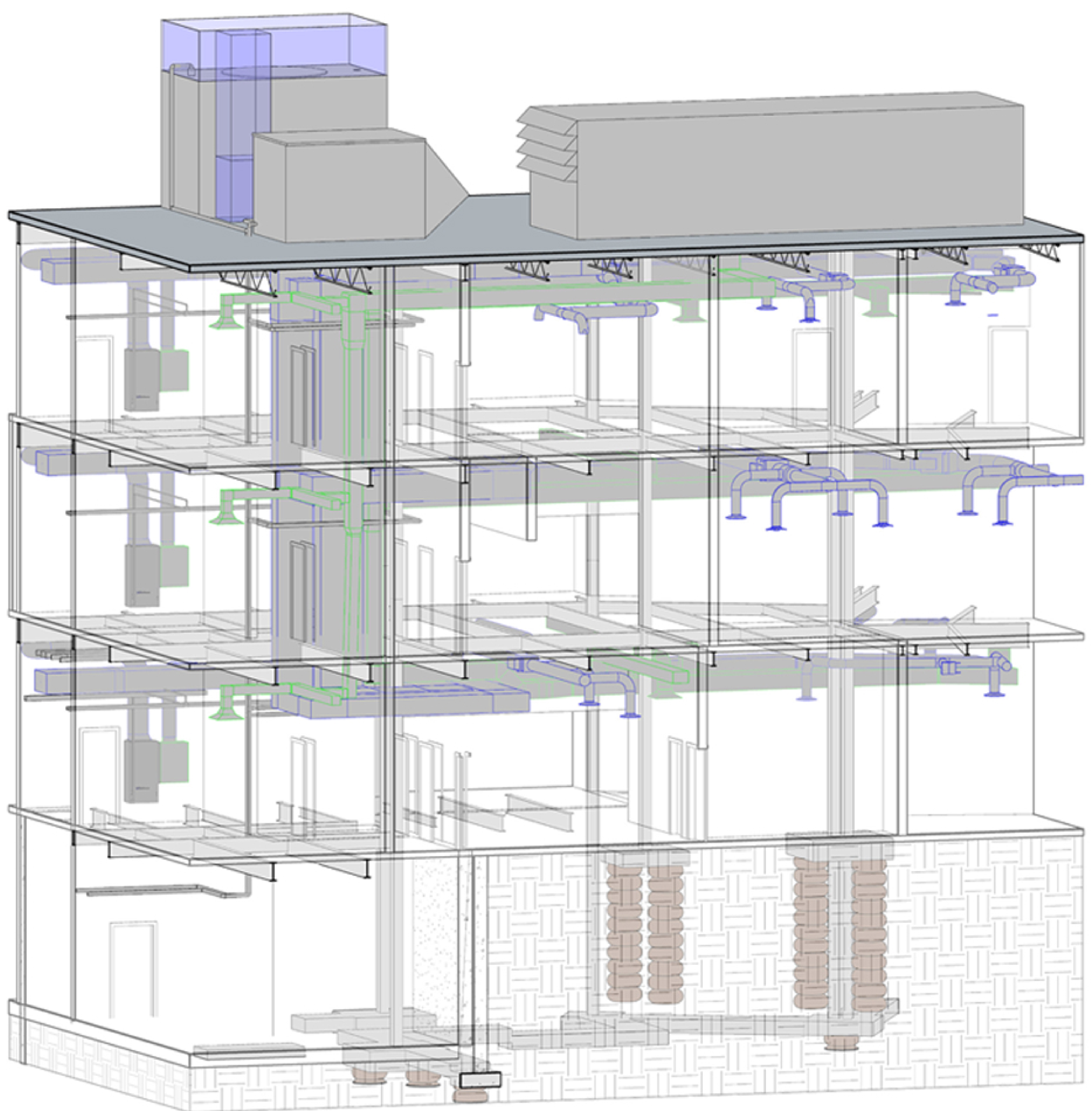
I-300

Scale



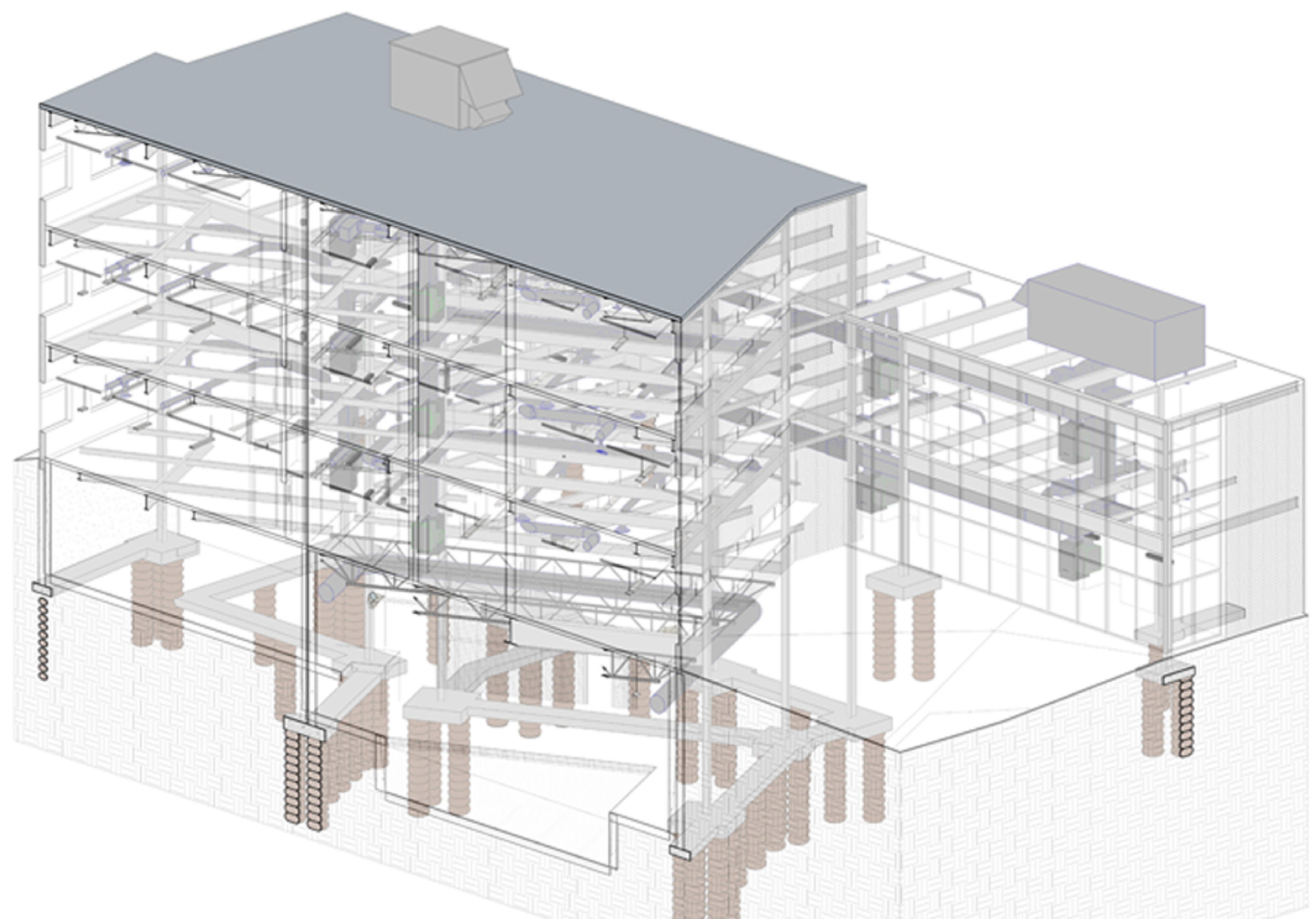
Rear Building Entrance Section





Core Shaft Section

The shaft spaces and the mechanical branches into the hallways was a highlight of integration for our team. Keeping the conections clean and presentable to occupants was a challenge that we were able to accomplish with the help of 3-D modeling technology.



East Wing Section

The east wing includes multiple classroms, and a unique large group instruction space that looks out onto the top of the green roof. The air handling unit on top of the green roof is easily visible to the students, allowing the teachers to more easily explain the building systems to the students, further reinforcing our design team's goal of using the building as a teaching tool.

AEI TEAM
10-2013

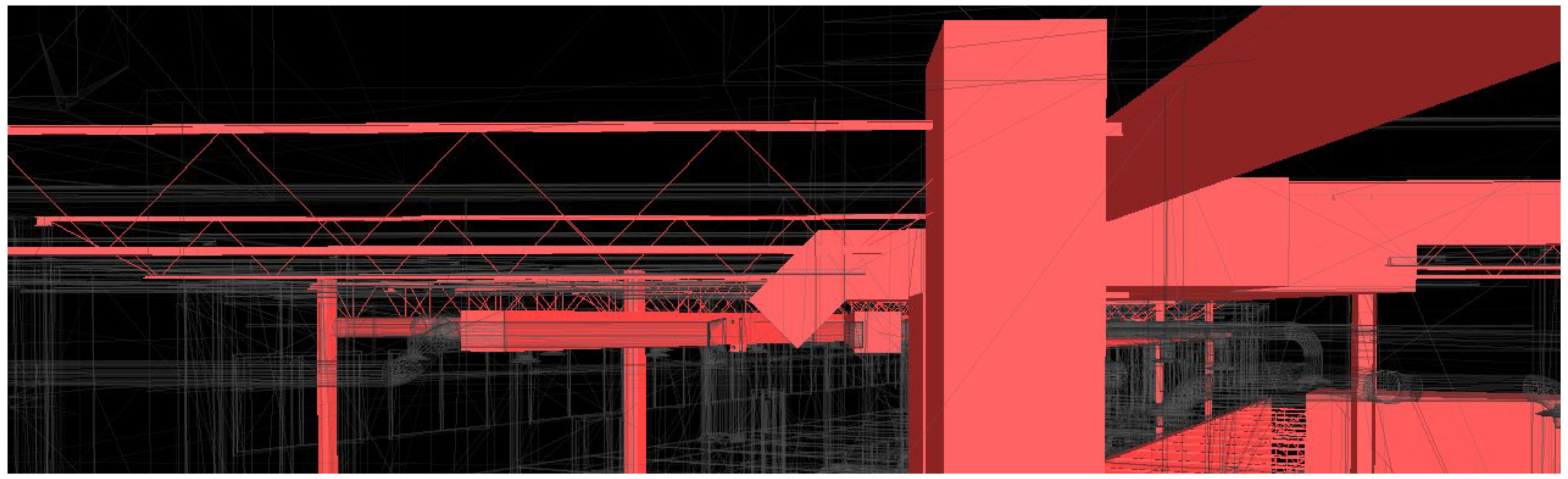
READING ELEMENTARY SCHOOL

BUILDING SECTIONS

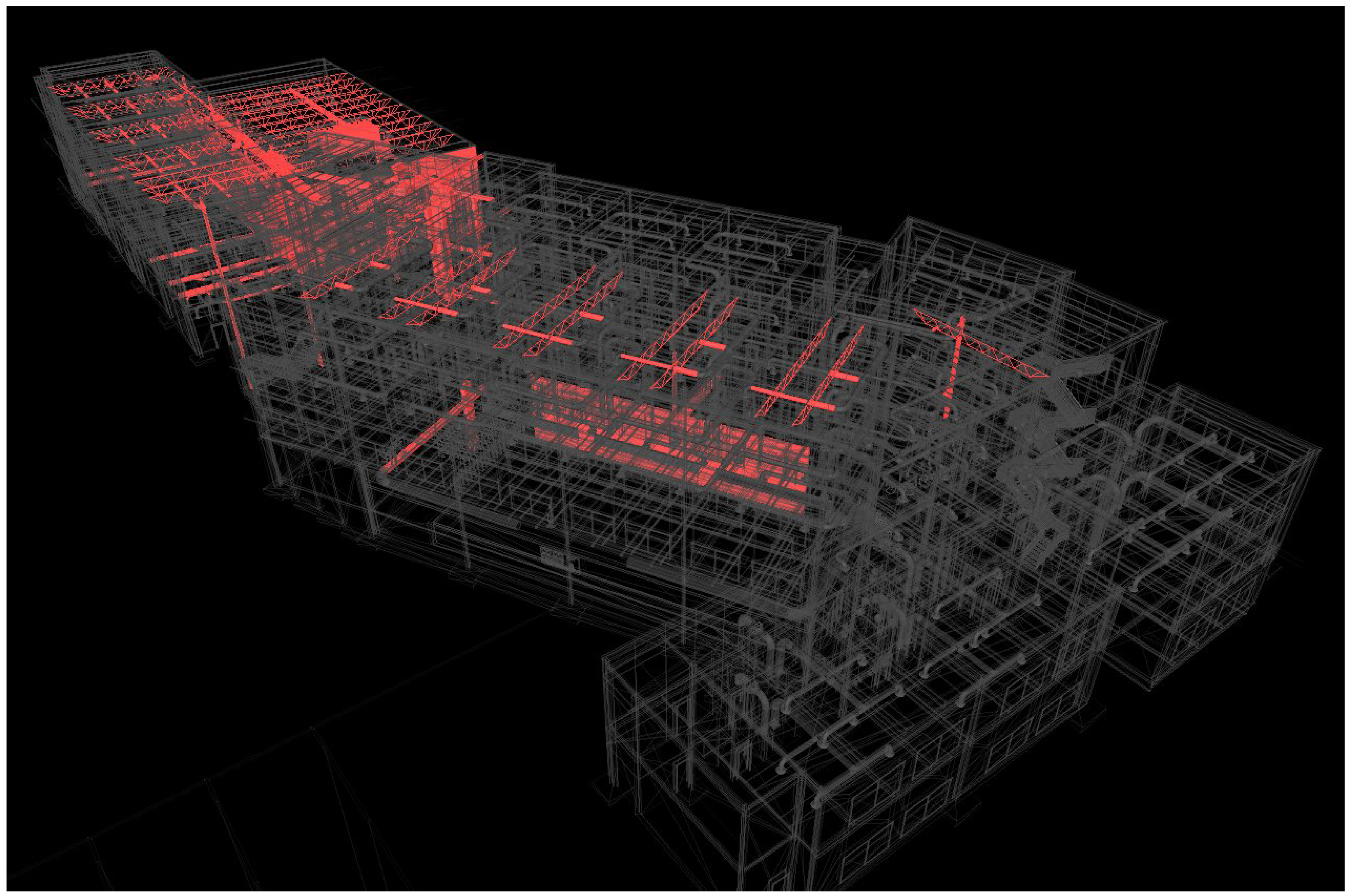
Date 02.22.2013

I-301

Scale

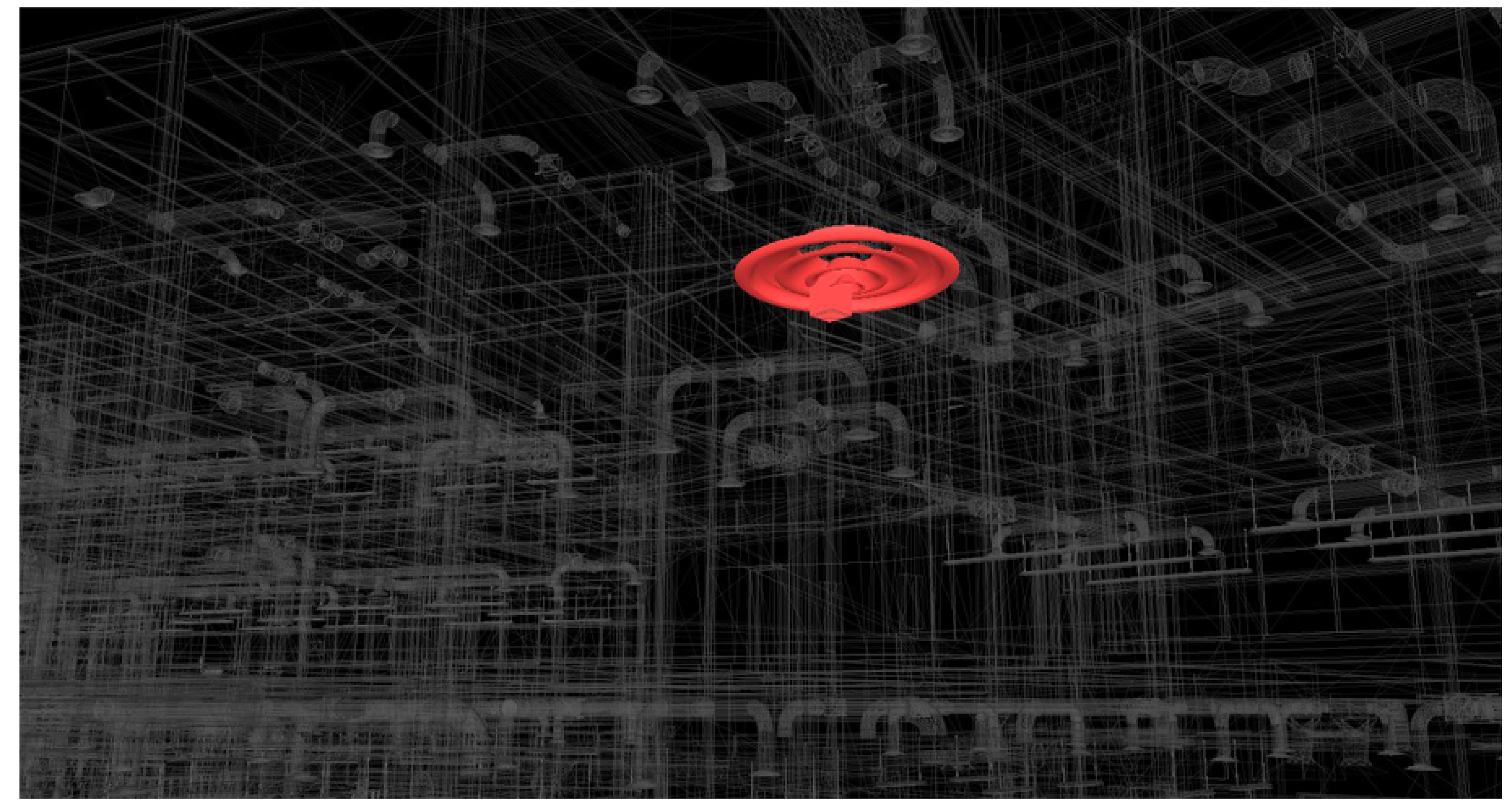


Structural/Mechanical Clash - Joist and Duct Riser



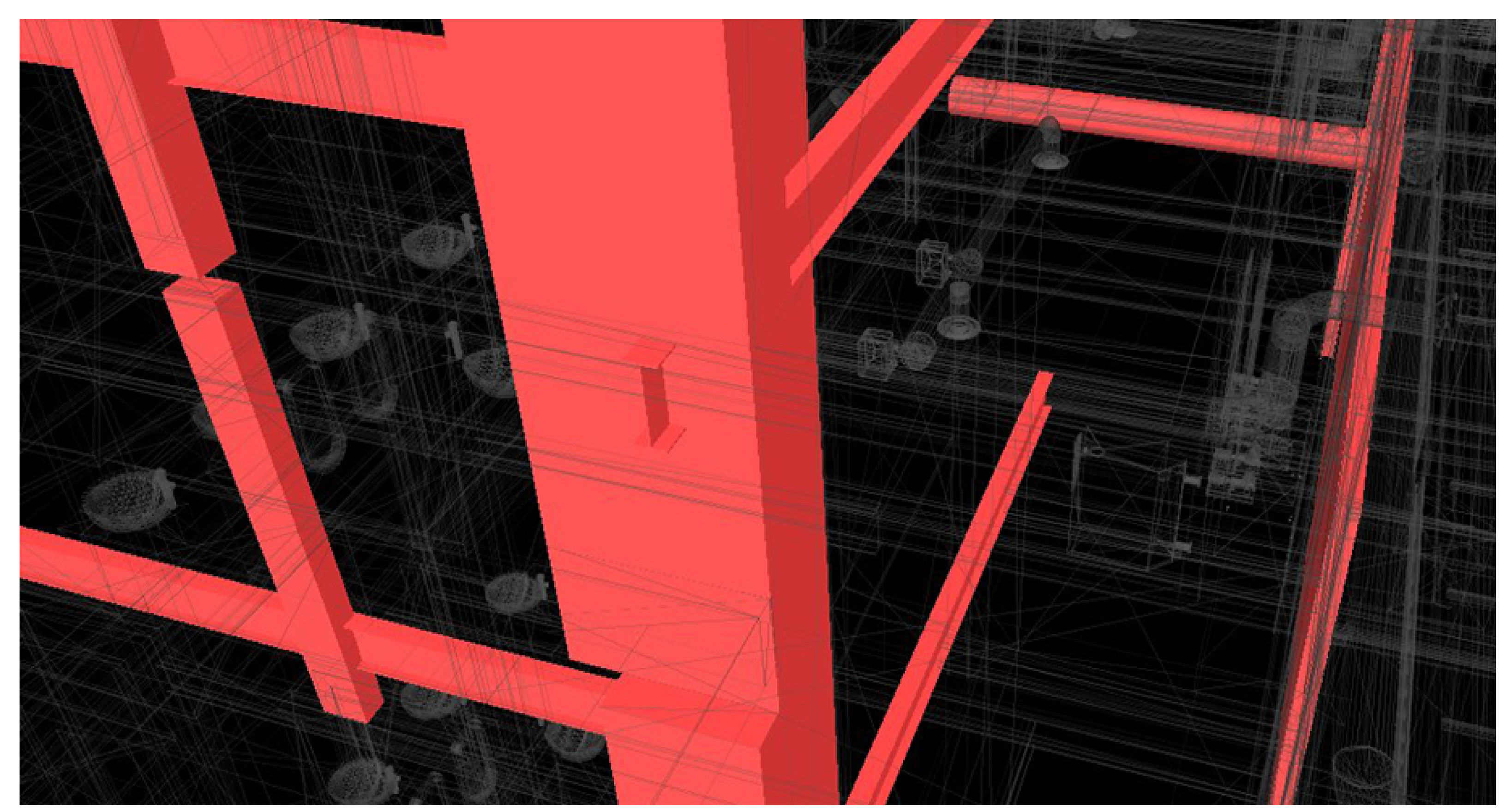
Building Systems Clash Detection using Navisworks

Revit to Navisworks workflow allows designers to detect potential clashes before the construction project begins. This alleviates any potential construction delays or change orders once construction is underway. By utilizing Revit, our design team was able to track interdisciplinary changes in real-time and be conscious of each discipline. The majority of clashes were between structural and mechanical systems. These clashes were resolved in a timely manner and before the construction project began. It is much easier to alleviate system clashes during the design phase rather than during construction. This workflow allowed our design team to complete the design on schedule with minimal coordination issues, which allows the project schedule to remain on time and contribute to greater owner satisfaction.



Lighting/Mechanical Clash - Multipurpose Room

Structural/Mechanical Clash - Multipurpose Room



Structural/Architectural Clash

AEI TEAM
10-2013

READING
ELEMENTARY SCHOOL

CLASH DETECTION

Date 02.22.2013

I-700

Scale