responsive frameworks

polyfunctional space for dynamic stimulus matthew colianni

A Design Thesis Submitted to the Department of Architecture and Landscape Architecture of North Dakota State University

By

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Fargo, North Dakota

This thesis titled “Resonsive Frameworks: Polyfunctional space for dynamic stimulus” investigates the question, “how does a building respond to dynamic stimulus?” Creating polyfunctional space through the use of kinetic components and flexible design solutions is the unifying idea guiding the research. A performing arts center at the Minnetonka Center for Arts campus is the building typology serving as a vehicle to explore the preceding areas of research. This 33,260 sq ft. center, located in Orono, Minnesota will expand the organization’s area of expertise to include the performing arts.

keywords

dynamic
flexibility
performing arts

how does a building respond to dynamic stimuli over time?

how does a building respond to dynamic stimulus?

how can a building dynamically respond to constantly changing environmental and programmatic factors?

how does space (a building) respond to dynamic stimulus over time?

the actor is the building

the action is the reponse

it does so over time

the dynamic stimuli is acted upon

typology	Performing arts center
claim	A diverse program informs flexible patterns of organization that can be modified as needs change over time.
premises	Performing arts requires various lighting, spatial qualities and diverse programming (inluding acoustics) to be created and recreated within the same space (Tisi Paredes, 2008).
	Similarities and differences between program elements inform combined design solutions.
	A flexible framework yields space that can adapt to user modification.
theoretical premise & unifying idea	Creating polyfunctional space through the use of kinetic components and flexible design solutions.
project justification	Conserving the embodied energy of the built environment by maximizing the effectiveness of space.

Historic and contemporary buildings are not unlike the human body. Both have a supporting structure; in the body it is the skeleton. It the foundation of the other members and without it the rest of the body would be useless. The organs bring life to the body in the same way the environmental control systems of a building provide air, electricity, water, and energy. The skin performs the same function as the building's envelope: it provides security, warmth and protection for the internal components and from external exposure.

Unlike the typical idea of building, humans are capable of great expression, adaptability, and healing. A boy's broken arm heals with time. The iris adjusts its size to see clearly in the dark, and our skin blushes with embarrassment. With our legs we run across an open field, and during exercise and our muscles build endurance and strength.

In comparison, a progressive collapse brings down an entire building. Insulation must provide a compromise between heating and cooling. Foundations crack under seismic activity. Only if the separate components become animate and alive can a building become as expressive as the living body. Through the use of kinetic technology, building components can actively provide a response to internal and external stimuli, and thus become like expressive creatures, full of life and motion.

This thesis seeks an architectural model that utilizes adaptive components to meet the needs of the present and future. Currently, buildings face short lifetimes, constant changes in ownership, change in typology, and a societal demand for building reuse. A performing arts center questions the ability for the same space to daily meet different needs, and will be used as the vessel for exploration. The space must also adapt to fluctuations in the weather and solar patterns of the region, representing an architecture that adapts to unanticipated needs.

In Orono, Minnesota this performing arts center serves as a demonstration of the expressive potential of kinetic building's components. In the visual arts, materials are manipulated by the artist to become the product of his or hers imagination. In the performing arts, the face and the body of the actor are part of the performance. This design is symbolic of the actor, shaping and reshaping itself in a performance that captivates the imagination of its audience.

user groups include, but are not limited to the following: visitors, performers, students, maintenance, instructors, technicians and administration

Owner: The owner and primary user of the center is the non-profit organization, Minnetonka Center for the Arts. Peak usage occurs during the daytime hours Monday through Saturday. Universal design guidelines will be heeded for any and all users with special needs or disabilities. Private parking will be provided for faculty and public parking available for all other users. Special considerations will be made for school bus and delivery trucks

The secondary users of the center are the surrounding schools that utilize the existing campus for educational outlets. This is mainly short-term student galas and performances. Monthly usage is anticipated from this group and will be highly encouraged for increased community outreach and economic benefit.

Client: The faculty is the daily and most frequent user of the facilities. There will be an administrative staff of office personnel handling the financial and business matters of the facility. There will be maintenance staff who will monitor the cleanliness and safety of the facilities. A small team of technicians will assist with lighting, acoustic design, and sound levels during performances. The instructors will teach classes daily and hold office hours along with the administrative staff.

The secondary group of primary users are the students of the facility. Students will use the facility daily during class periods,and during performances. Groups of small classrooms will rotate class periods frequently, providing substantial traffic throughout the building.

The least frequent but highest traffic volume users of the facilities will be the visitors. Although infrequent visitors arrive in large numbers to observe performances and attend galas. Visitors include teachers and students not enrolled at the center using the facilities for short term purposes.

Theater: A theater used for performances including a stage, universal seating and audio control booth.

Storage & Set: Large warehouse space for set building and storage. This will be easily accessible by the theater and will have a loading dock.

Changing Rooms: Locker rooms for the students who will be performing or rehearsing. These will be adjacent to the theater and rehearsal rooms, and separated by gender.

Locker Rooms: Dedicated storage for costumes and intruments that will be used daily and accessed more frequently than properties in the warehouse.

Maintenance: All maintenance equipment, including janitorial facilities, security systems, and sound equipment.

Mechanical: Space for the building's environmental control systems and their operation.

Lobby: A public lounge, vestibule, and reception space for the visitors to the facility.

Parking: Private parking for faculty and staff. Public parking for students and visitors.

Studio Classrooms: Flexible rooms with moveable furnishing for a variety of classroom settings.

Restrooms: Sufficient restrooms for the administration, classroom, private and public zones of the facility, according to universal design principles.

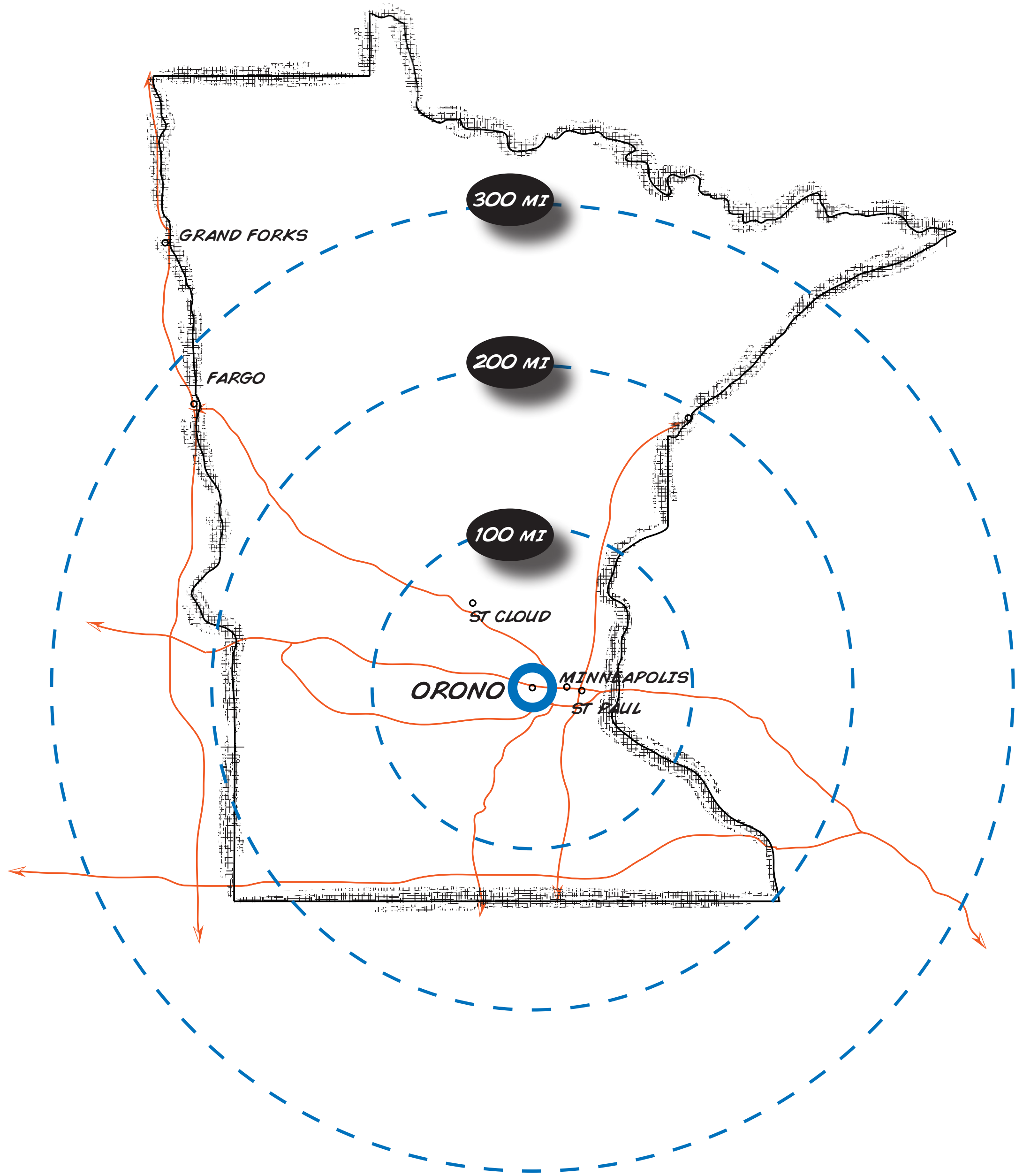
Audion & Video Booth: Projection room with access to sound and lighting equipment for the theater.

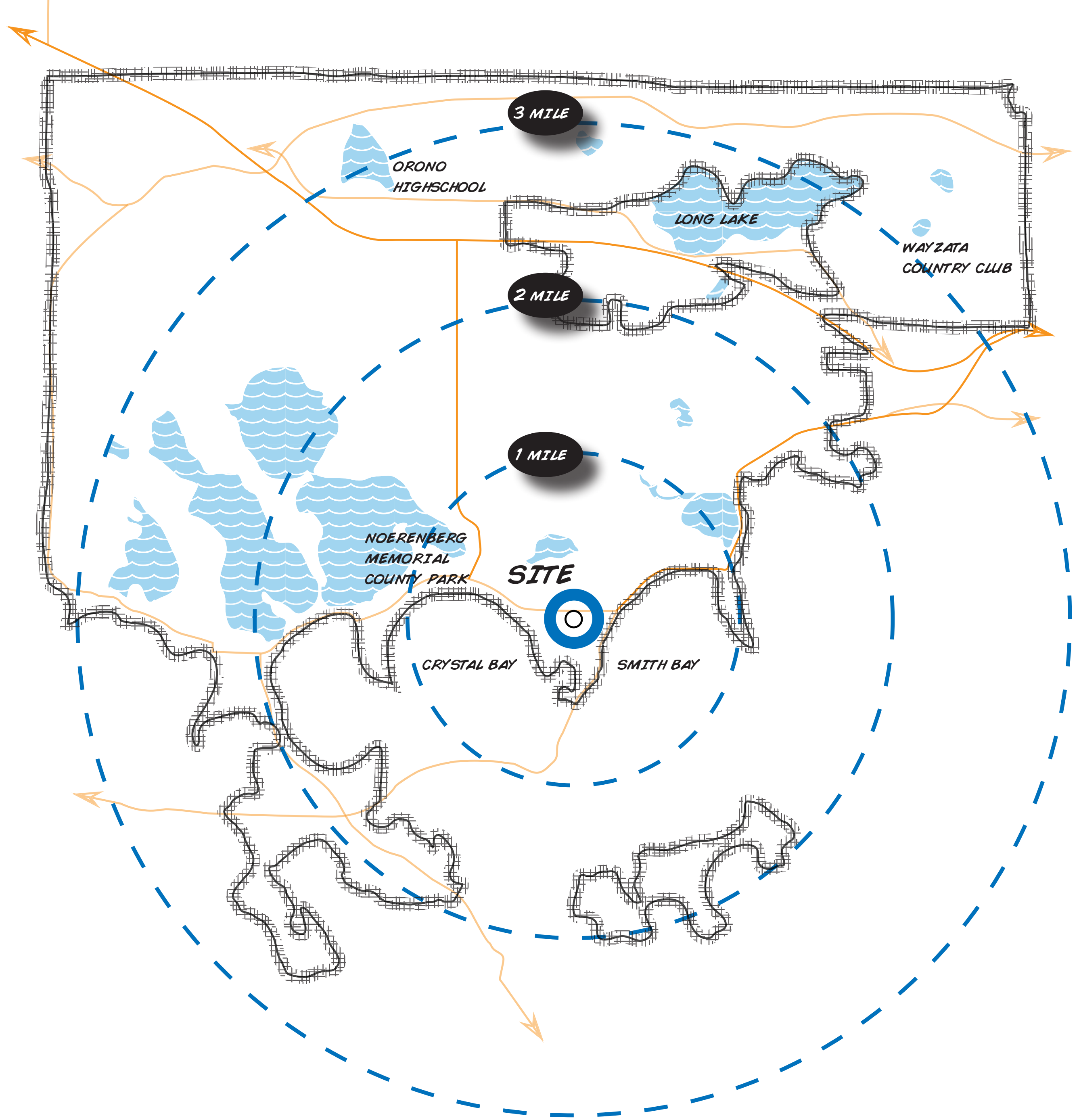
Region: The proposed site location is in central Minnesota. Summers are warm and are followed by cold and icy winters. There is an abundance of lakes and parks in Minnesota.

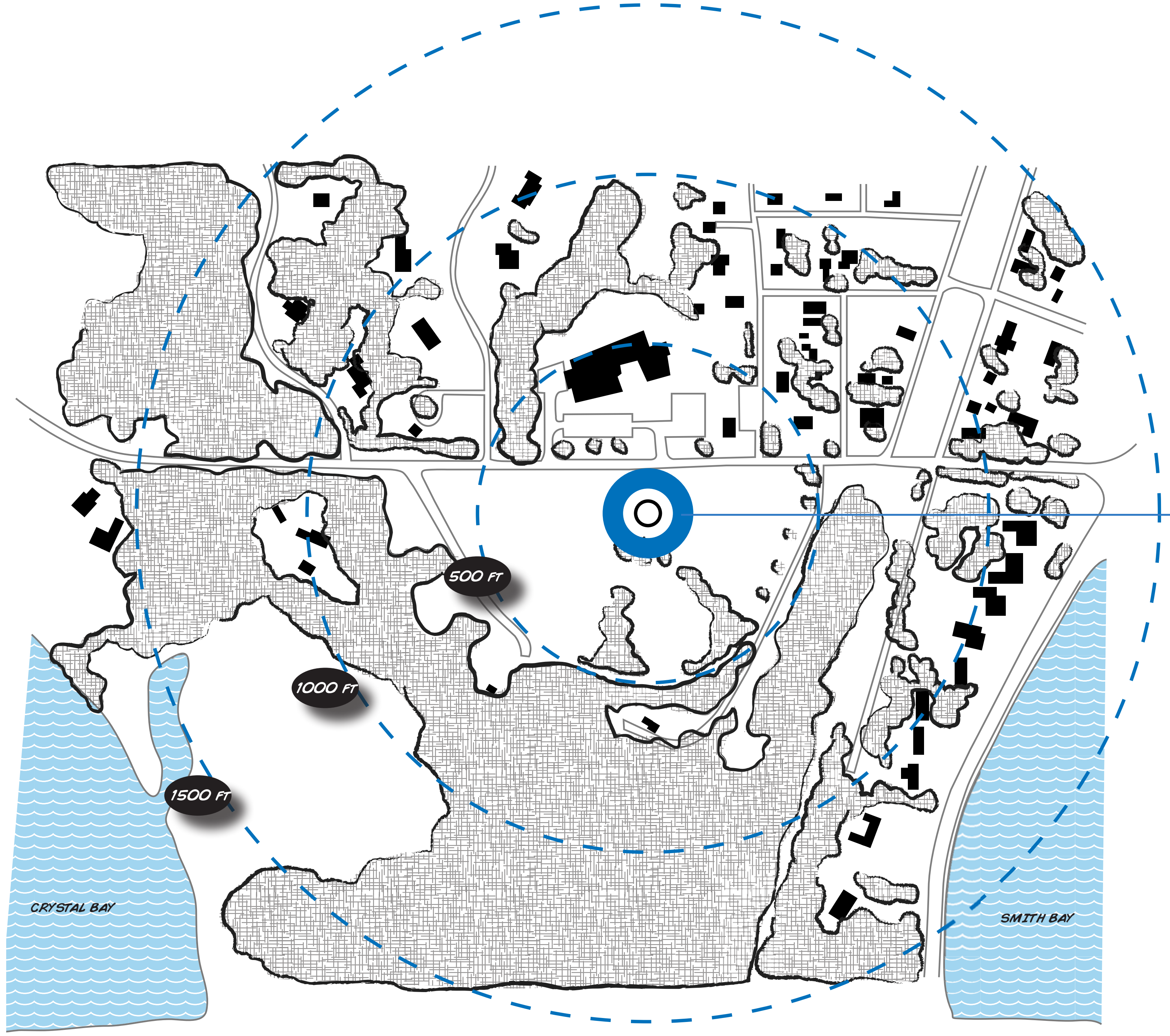
City: Orono is a city in Hennepin County. and is home to roughly 7,500 people. The city limits occupy 25 square miles; 65% is land and 35% is water.

Site: The site is an extension of the existing Minnetonka Center for Arts campus. The Center is within close proximity to major highways connecting the south western suburbs to Minneapolis and Saint Paul. Another outstanding feature is the short distance to the Dakota Regional Trail, a 13.5-mile paved biking and walking trail extending from Wayzata to St. Bonifacious.

Further Notes: There are two existing commercial structures in close proximity to the site; The Minnetonka Center for the Arts, and the Creative Kids Academy (ckakids.com). Initial research indicates that neither structure will be removed or modified to accommodate the proposed building. Careful site selection preserves all existing commercial and residential properties.



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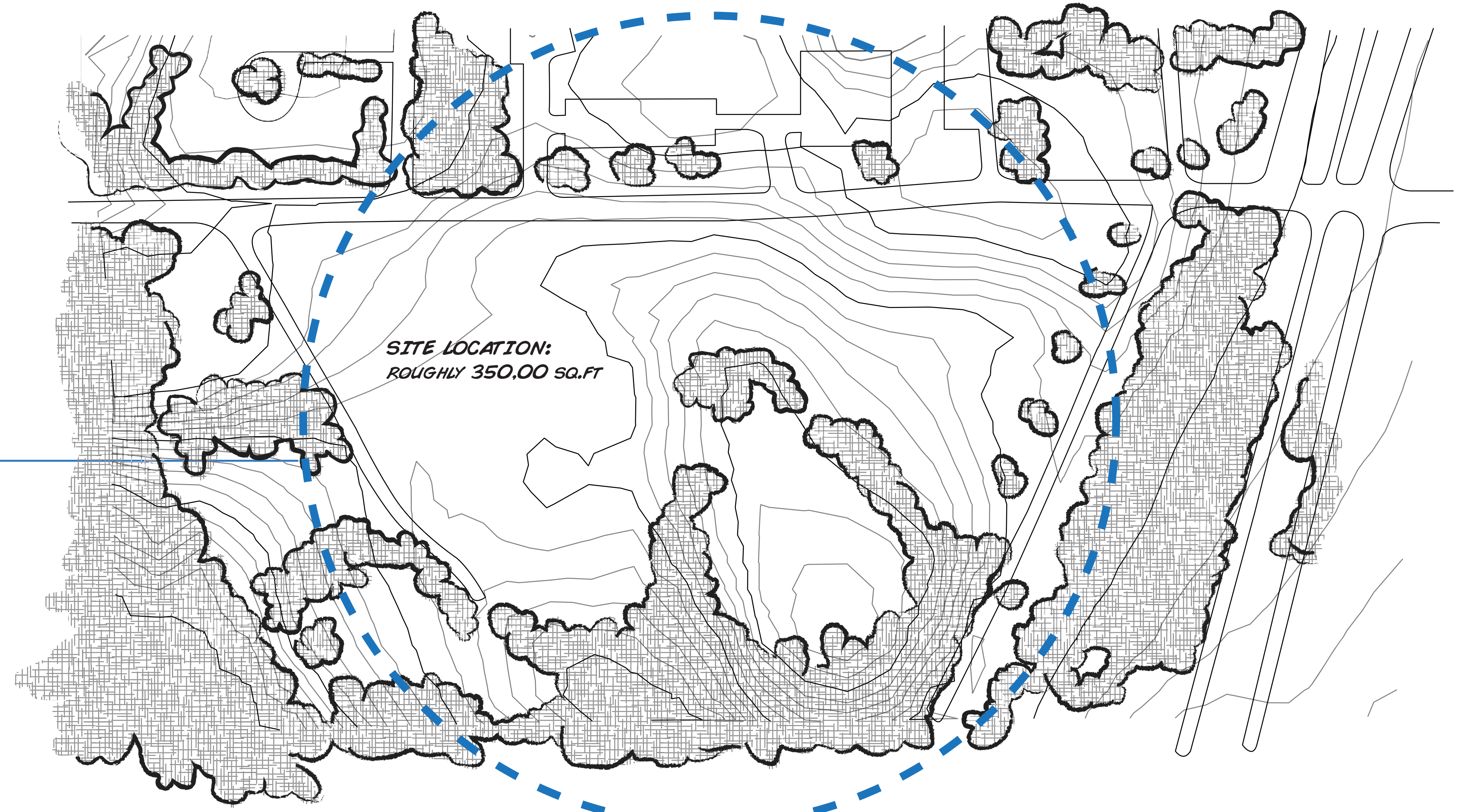
CRYSTAL BAY
SMITH BAY

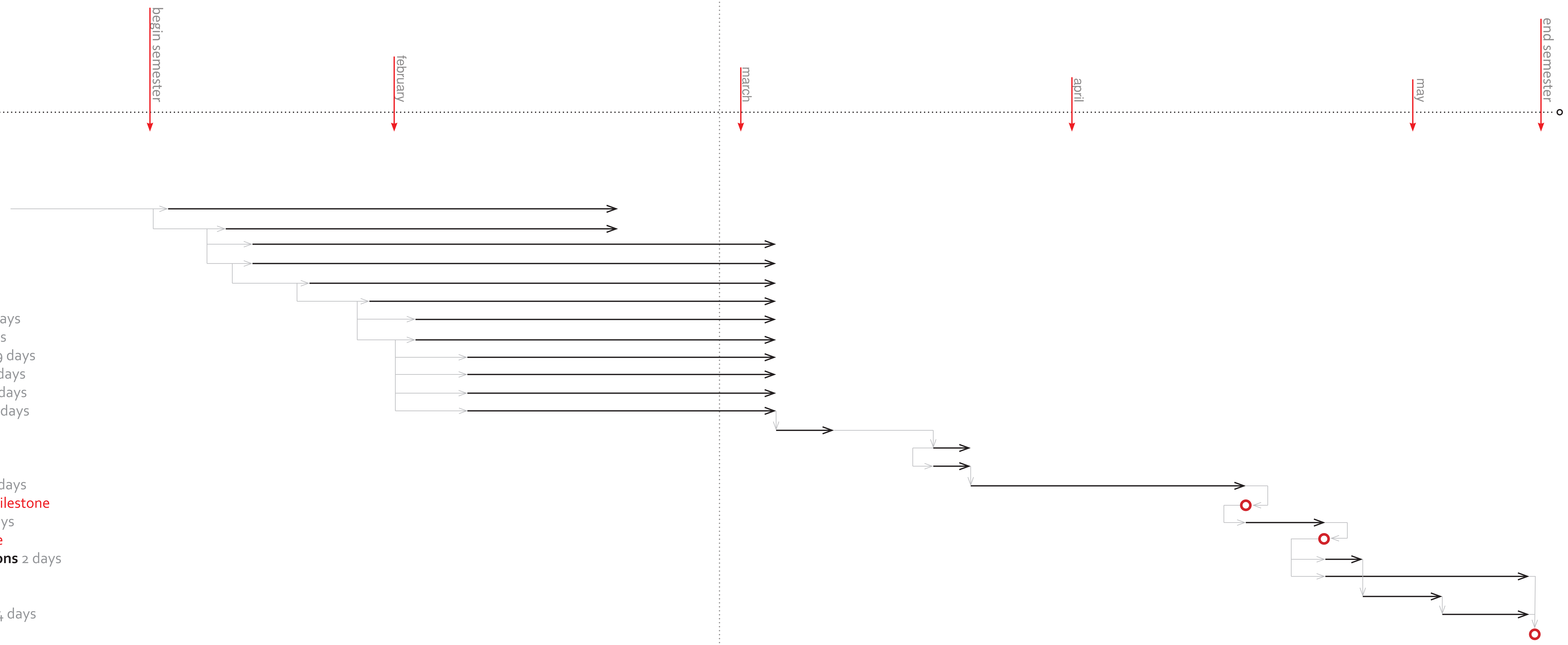

SITE LOCATION:
ROUGHLY 350.00 SQ.FT

responding to dynamic stimuli through the use of modifiable space is the emphasis of this project.

Research Direction: An examination of the theoretical premise will be critical to research development. An analysis of the site, its history, and climate conditions will inform a response for the building systems and materials. The historical use and innovation of kinetic technology will be investigated. A complete understanding of the programmatic requirements and an understanding of the evolution of the typology will be also be explored.

Design Methodology: The design method used will be the mixed method or qualitative/quantitative approach. This method makes a comparative judgement from the analysis of both qualitative and quantitative data. The quantitative data is objective and includes numbers and figures, structures and load calculations, materials, and dimensions. These can be studied numerically and scientifically. Qualitative data is the subjective analysis ranging from theory and method to design aesthetics. Contrary to quantitative data, this is based on perception rather than calculation.The focus of the data collection is the theoretical premise and unifying idea as well as the context of the site and project typology.

Documentation: Significant research discoveries, substantial design progress, and key decision making will be chronologically documented to demonstrate thought process, progression, project transformation, and design method. This includes but is not limited to scanning two-dimensional productions, photographing three-dimensional models, and keeping a collection of any additional physical and digital resources. This area of documentation should provide insight into the design desicions that are relevant to the typology, unifying idea, project emphasis, and additional areas of research task & duration



1 context analysis 28 days
2 concept analysis 25 days
3 spatial analysis 33 days
4 structural analysis 33 days
5 ecs passive analysis 34 days
6 ecs active analysis 25 days
7 floor plan development 20 days
8 section development 20 days
9 structural redevelopment 19 days
10 envelope development 19 days
11 materials development 19 days
12 context redevelopment 19 days
13 midterm reviews 5 days
14 project revisions 2 days
15 presentation layout 2 days
16 project documentation 18 days
17 cd due to thesis advisors milestone
18 plotting and modeling 5 days
19 exhibits installed milestone
20 preparation for presentations 2 days
21 thesis exhibit 15 days
22 final thesis reviews 6 days
23 final thesis document due 4 days
24 commencement milestone

Fall 2008
Heather Fischer & Meghan Duda
Tea House: North Dakota
Minneapolis Rowing Club: Minnesota

Spring 2009
Mike Christenson
Dance Studio: North Dakota
Material, Place, Time: North Dakota
Pritzker Analysis

Fall 2009
David Crutchfield
Probstfield Farm Historic Center: Minnesota
Snow Symposium
NDSU Branch Library: North Dakota

Spring 2010
Cindy Urness
Natatorium: Indiana
Biker Bar: North Dakota
Multi-Modal Transit Center: North Dakota

Fall 2010
Frank Kratky
Mixed Use High-Rise: California
KKE Competition

Spring 2011
Don Faulkner & Frank Kratky
Marvin Windows Competition: North Dakota
Williston Master Plan: North Dakota

Fall 2011
Mark Barnhouse
Water Property Analysis
Water Resource Experiment Station: North Dakota

Spring 2012
Bakr Aly Ahmed
Design Thesis

Theoretical Premise & Unifying Idea: Utilizing kinetic technology and design flexiblity to create polyfunctional space.

Introduction: The research results are derived from the theoretical premise/unifying idea. The following points of research seek to comprise a holistic understanding of the selected typology and the theoretical premise: design recycling, sustainability, kinetic design, acoustic design principles, and energy. The purpose of the research is to explore the interactions each topic has with the others and their corresponding relationship to the project emphasis. Finally, contextual analysis of current trends in live performance and theater design is the framework for application of the results.

Kinetic Design: Presently a variety of definitions of words like adaptive, dynamic, and kinetic when paired as an adjective to design, result in confusion and misapplication of theory.

Dynamic is often tied to the form of an object that does not imply that it contains or exhibits energy, but rather that energy and motion are implied. This is characteristic of the sculptural works of architects Frank Gehry and Zaha Hadid, but the term "dynamic" does not often describe actual motion. Although the word adaptive is accurate to the functionality of kinetic architecture, it is more commonly used to describe the reuse of old structures and has no strong connection to kinetic architecture.

Kinetic arts, as defined by Tom Porter in his book *Archispeak,* is "A term...to describe an art form, usually sculpture, that incorporates real or apparent movement" (Porter, 2005; page 84). Putting aside the theoretical debate of art and architecture, the definition of kinetic architecture is then a subcategory of the kinetic arts.

Rather than explicitly defining kinetic architecture, Porter proceeds to cite examples of built work. Excluding amusement parks and theme parks, Porter describes a stadium in Japan and a bridge in England. What these projects have in common is the utilization of moving parts.

There is a necessary distinction to make between what can be derived from Porter's description and what we utilize daily in the built environment.

Windows and doors themselves are moving parts, but this eludes the reference. An important distinction to make is that kinetic is not defined by scale. A 3,400 sq ft recital hall dubbed the Wild Beast in California and the previously mentioned Sapporo stadium in Japan are two examples of kinetic architecture with a dramatic difference in scale. It is their consecutive use of moving parts that classifies them as kinetic. Machines, robotics, electronics, and the future use of nanotechnology to enable motion distinguish kinetic. Kinetic systems respond to change through motion.

Currently there are three ways of understanding the application of kinetic architecture. Motion can provide an aesthetic quality, it can serve a functional purpose that cannot be performed otherwise, and it can be a response to an environmental control.

A lift bridge in Duluth, Minnesota raises itself when a large boat is passing underneath and lowers itself again for cars and pedestrian traffic. This would not be possible if the bridge remained in a static position. The Gateshead Millennium Bridge in England, Tom Porter's reference to kinetic architecture, performs the same function.

David Fischer's proposed rotating skyscraper in Dubai is a series of prefabricated twisting floor plates mechanically attached to a solid core. Although the functional purpose of a rotating building and the logistics of its rotations remain unclear, the architect and press are excited by the ability "to twist the entire building into different shapes" (Mckeough, 2005; page 38). This building uses kinetic technology to acheive an aesthetic response to an internal stimulus.

Finally, there is motion in response to an environmental control. Santiago Calatrava's Milwaukee Art Museum addition raises a wing like brise soleil, or sun breaker, daily to shade unwanted glare and solar heat gain from the expansive glass cathedral ceiling. The wings lower at speeds greater by automatic sensors at speeds of more than 35 mph as a safety precaution. This design provides overlap between the aesthetic expression and the environmental control, or form following function.

The project emphasis states a response to internal and external stimuli through the use of kinetic technology. This is the overlap of kinetic architecture creating motion in response to environmental controls (external) and programmatic functional needs (internal). The resulting motion is an aesthetic expression, rather than seeking an aesthetic expression in itself.

Some technologies currently exist drawing inspiration from other fields. The Wild Beast's acoustic louvers use actuators used in aviation design. Electrochromatic glass can change opacity by means of an electric current. This technology is also used in the automotive industry. The expression in these examples is the outcome rather than the means of acheiving that result.

A bathroom partition could be made of electrochromatic glass, tinted while in use and clear when vacant to allow more light into the interior of a narrow building or dark interior. In this example a kinetic component can satisfy two functions, and the expression is a technological adaptation to change. Rather than seeking aesthetic qualities for the sake of design, this thesis seeks the use of kinetic technology as a sustainable strategy. The goal is to improve the building's flexibility, creating a polyfunctional space that uses fewer resources than its traditionally built static counterpart could.

A space with the ability to transform over short periods of time can serve various functions within the same space. This amounts to less interior volume, a smaller envelope, fewer resources required for construction, lower maintenance costs, and a smaller heating and cooling load.

A space with such flexibility could perform many functions for many people. Such a model is sensitive to the future. Although unaware of its future needs (what it will be today, and tomorrow, and a decade from now), it is ready to adapt to the need.

With today's buildings facing shorter lifetimes and changes in ownership happening faster than ever, it is important to build space that can adapt to change. Such a building is a model for sustainability, and that meets the needs of today, tomorrow, and the future.

Design Recycling: While this project is not an adaptive reuse project, the outcome seeks to be a model for future adaptability. Design recycling or building reuse is an old trend receiving recent attention. The prestigious *Architectural Digest* has been showcasing adaptive reuse residential projects for more than 20 years (Stephens, 2008).

Reuse is popular both as a starting point for a design artifact and in the sustainability movement. Reuse projects are well known for providing attractive contrast between old and new, and for the use of materials and textures (Stephens, 2008). Reuse is popular among sustainability and green building projects for the waste reduction potential and embodied energy savings.

Embodied energy is a measure of the building's lifetime; from construction, to its life as a building, its daily operations and its ultimate deconstruction or deterioration. Some buildings are not built to last long and a short building lifetime has a high ratio of embodied energy use. When an old building shell

or structure is re-purposed, the initial material and construction lasts longer and saves it from early deconstruction and time in a landfill. The embodied energy is therefore lower because it eliminates the process of possible demolition and rebuilding at the site.

North Dakota State University's art and architecture program is currently residing inside the shell and modified structure of a 100-year-old farm implement warehouse. Imagine the energy it would have required to tear down the entire building and construct a new one. The embodied energy of a completely new building is simply astronomical.

Future reuse can be implemented by studying the current selection of popular reuse candidates. Notable features that are incorporated into design include heavy structures, flexibility, and long-term durability of materials. Warehouses are good donors because of the flexibility of the open layouts, long span structural elements, and the strength of time-tested materials. Heavy lumber, cast-in-place concrete, and true masonry are recurring elements.

Design recycling is an important discussion in the field of kinetic architecture in anticipation of future adaptability. Choice of material and layout flexibility are important choices that impact not only daily operations but also the unanticipated needs of the future. As stated before, a kinetic building is a flexible building and therefore a sustainable building.

Sustainability: Kinetic design can also be incorporated into the basic building design which is perhaps the most significant sustainable measure a designer can take. Basic building design is the basic form, the site orientation, window size and location, envelope size, and any other preliminary decisions made in the beginning stages of building design.

Solar geometry, day lighting, and the microclimate of the site are the primary factors that influence the basic building's design. Utilizing natural lighting can provide a significant savings on the energy used for artificially lighting a room. Passive ventilation can significantly decrease the cooling load of a building, and south-facing fenestration will greatly reduce the heating load of a space. Even natural landscaping, trees, for example, can provide shading in the summer.

Kinetic design provides opportunities in addition to the basic building design to assist with the day lighting, heating, and cooling a building. Solar geometry changes considerably during the day and during the year. The sun is higher in the summer and lower in the winter. These frequent changes require smart components that can adapt to change.

Climate is defined as the annual data collection, and weather is the daily calculation. While such factors are predictable, a passing cloud is unpredictable. Smart components would react not only to weather and climatic conditions, but also to the unpredictable daily factors of a site. For example, the wind speed sensors on Calatrava's museum addition in Milwaukee adjust to the uncontrollable daily wind speed.

These daily factors are highly related to the programmatic function of a building. Allowing light where light is wante d and from where it is provided, blocking unnecessary heat gain and glare where it is undesirable, and using wind as passive ventilation are a few possibilities. Kinetic systems have the potential to vastly improve energy savings when added to the basic building design desicions.

Furthermore, good design is sustainable design. People take care of the buildings they love, and those buildings have a longer lifetime, utilizing the embodied energy of their construction and material usage to the fullest. When we love our buildings we preserve them and they continue to sustain us.

Energy: In the study of kinetic architecture, a basic understanding of kinetic energy cannot be ignored.

Kinetic energy is the opposite of potential energy. A basic description is that kinetic energy is energy in motion, and potential energy is its counterpart. It should be no surprise that kinetic architecture is deeply involved with kinetic energy; their marriage predates the use of the windmill.

As the sustainability of our built environment increasingly becomes an issue, scientists, engineers ,and architects are revisiting the past in new ways. Wind farms and solar farms are two ways we are looking to renewable energy to power the future.

Kinetic architecture offers exciting new opportunities for renewable energy sources. Club WATT in Rotterdam turned to the company Sustainable Dance Club (SDC) for a dance floor that converts the dancers' movements on the dance floor into usable energy. Club WATT is reporting a 30% energy reduction compared to other nightclubs.

This is made possible by the piezo effect. Internal generators underneath the floor release energy, or piezoelectricity, when compressed. The electricity can then be used by the building or fed back to the grid. The piezo effect can be used to capture any vibration, which would otherwise be lost energy.

Something as small as a footstep can be a source of renewable energy.

Regenerative energy is also used in the automotive industry, assisting hybrid technology in fuel savings. Capturing lost energy through kinetic systems as a renewable energy source offers exciting new opportunities for architecture.

Sound: "Whether low or high frequency, man-made or natural, noise is the bane of modern living" (Hart, 2005; page 143).

Acoustic design cannot be understood without a basic vocabulary. Sound is either wanted or unwanted. Noise is the definition of unwanted sound (Lamuth, 2008). Sarah Harts article *The art and science of peace and quiet* describes the presence and magnitude of unwanted noises in New York, a dense urban environment. She describes the difficulty of isolating unwanted noise from the interior of a building. Unwanted noise is also generated within buildings daily, rural and urban. "Even people hermetically sealed in office buildings suffer from disruptive noises created from within — humming light fixtures and air handlers, distracting conversations, and ringing phones" (Hart, 2005).

Acoustic design solves two problems. How do we isolate unwanted noise and capture wanted sound? Wanted sound includes the speaker in an auditorium, the music of an orchestra, and the singing at an opera, for example.

The difference between noise and sound can be measured scientifically, but can also differ subjectively from person to person. The important distinction to keep in mind is that noise is unwanted; sound is tolerable and sometimes wanted.

Sound is a wavelength produced by vibration. Wavelengths exhibit behavior, and two sound wave behaviors fundamental to understanding acoustic design are reverberation and absorption.

In *Acoustic absorbers and diffusers,* Trevor J. Cox and Peter D'Antonio define reverberation as "The decay of sound after sound has stopped" (Cox & D'Antonio, 2009; page 7). Hard surfaces produce reverberation, or echoes. These echoes can be good or bad, either filling space with distracting noise, or focusing wanted sounds. Reverberation is the sum of two variables, the size of the space and absorption of its surfaces.

"Live" and "dead" space is the perception of reverberation. Soft absorptive surfaces absorb the vibration of sound wavelengths producing "dead" or quiet space. A cathedral is a "live" space, a large space with hard reflective surfaces. The sound wavelengths reflect off the surfaces and have a large space to fill.

A performing arts center requires both live and dead space for different functions. Sound recording, black-box theaters, and rehearsal studios are dead and should be free from unwanted noise. Recital rooms and auditoriums are live, finely-tuned spaces delivering sound away from the stage and toward the audience.

According to David Egan in *Architectural Acoustics*, the distribution of sound can be understood like the bounce of a billiard bill. Simply stated, the angle of incidence equals the angle of reflection. This phenomena is also evidenced by measuring the specularity of light reflections, therefore light and mirrors can be used to measure sound distribution on scaled models and drawings. (Egan, 1988; page 95)

Designing with Sound: Sound isolation is a unique feature of performing arts design, especially with the newfound complexities of the genre. "Cultural complexes are evolving into multipurpose arenas in the same way that sports arenas have morphed into retail and entertainment venues. This trend will continue" (Hart, 2003). The purity of sound within the "shoebox" theater is gone, and structure is evolving to meet the required acoustic flexibility of the spaces. One method uses structural and acoustical joints, or breaks, in the steel and concrete to separate noise. Another method is a literal "box-in-box" (Hart, 2005) separating stacked noisy space with the use of floating walls and ceilings.

Much like the Americans With Disabilities Act and the Uniform Building Code, code performance standards exist for the acoustic design of buildings. Sound Transmission class (STC) is "A method for laboratory measurement of the sound transmission loss of materials and building systems" (Cavanaugh, Tocci, & Wilkes, 2009; page 85) established by the American Society for Testing and Materials (ASTM). Similarly the American National Standards Institute (ANSI) "Establishes methods for evaluating sound in rooms" (Cavanaugh, Tocci & Wilkes, 2009; page 85). One of three such measurement is noise criteria (NC).

The two measurements are used by architects to evaluate the appropriateness of space without the extensive testing already done by ASTM and ANSI. The numeric values are a quick reference to the spatial and material requirements of defined spaces. Examples from the Whole Building Design Guide provided by the National Institute of Building Sciences include: auditoriums, classrooms, and places of worship.

Sustainability and kinetic design are topics that address and provide insight into the theoretical premise/unifying idea and project emphasis. Acoustic design is a typological study for this thesis, and kinetic energy is a possible outcome of kinetic design technology.

Sustainability and kinetic design merge at the project emphasis, creating adaptation to both internal and external stimuli. External stimuli are defined by weather patterns and the various environmental factors a building will face in its lifetime. Some, like climate patterns and sun angles, can be calculated, while other changes, like wind, are unpredictable. Kinetic design is a supplementary solution to already implemented sustainable strategies. The advantage is change through motion performing functions that a static object is incapable of.

Kinetic designs offer the same advantage through responding to internal stimuli. Internal stimuli are the changes in functions that occur inside a building that can be both varied and numerous. The use of kinetic technology can merge several programmatic requirements in a single polyfunctional space, and flexibility is another sustainable strategy. Incorporating flexibility is an efficient use of materials and operating energy, and is capable of meeting the daily needs of operation as well adapting to the unpredictable needs of the future. Thus a kinetic architecture can become the model for future reuse, longevity, and resourcefulness of embodied energy.

Further avenues of research included sound principles and kinetic energy, concluding with current trends. Performing arts design and acoustic design today requires architects to incorporate flexibility into program and sound, creating new complexities and innovative solutions.

Finally, kinetic architecture is capable of transforming the energy from something as small as a footstep into a source of renewable energy. Kinetic design is responsible for motion in architecture, which addresses the needs of each avenue of research. From flexibility to renewable energy, motion, as a result of change satisfies, the theoretical premise/unifying idea in the pursuit of expressive architecture.

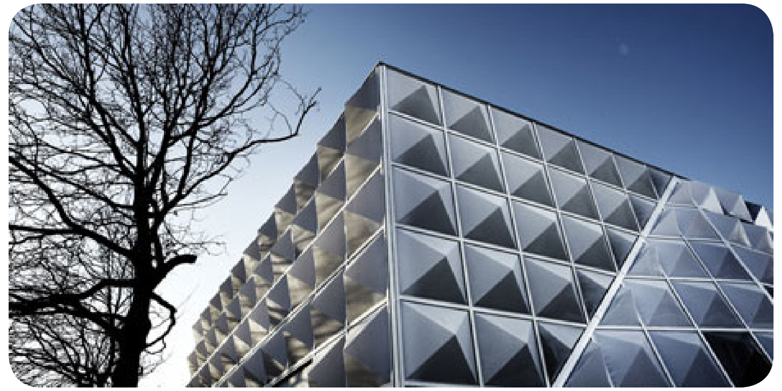
case study 01/03
architect enrique krahe
project municipal theater of zafra
typology performing arts/community
location zafra, spain
size 2763 sq m.
date 2009

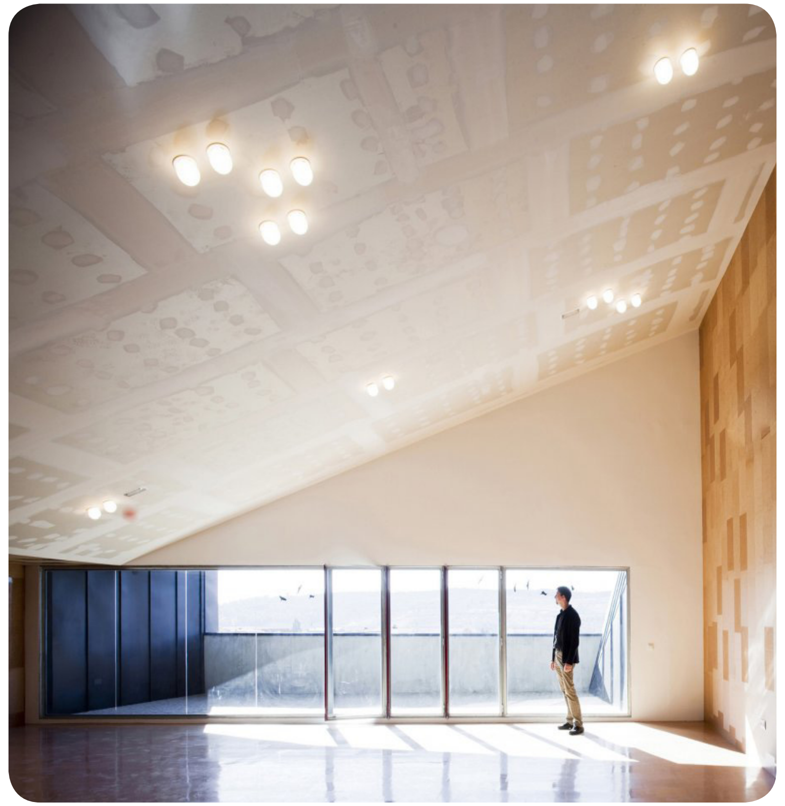

(fig 1.1)

case study 02/03
architect hodgetts + fung
project the wild beast
typology recital/outdoor stage
location valencia, california. US
size 3500 sq ft.
date 2009

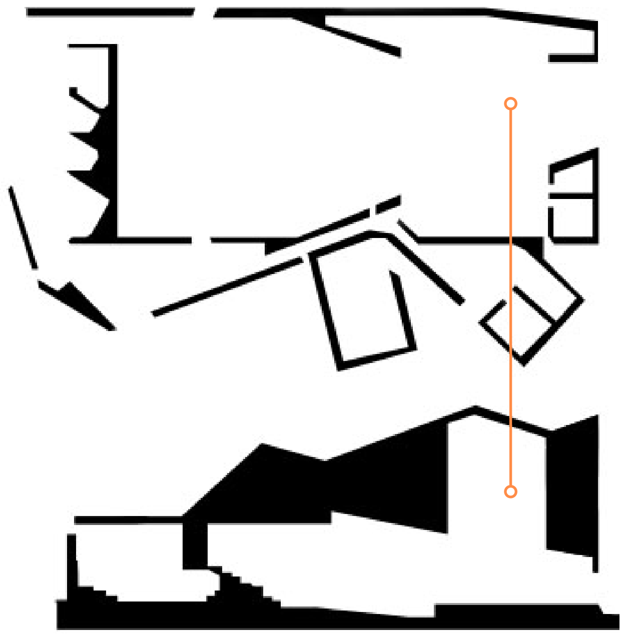
(fig 1.2)

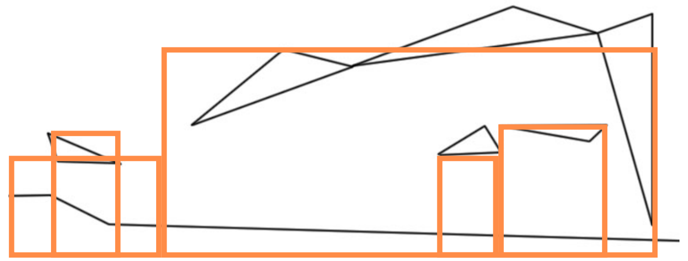
case study 03/03
architect kobe
project taastrup theater
typology renovation/theater
location taastrup, denmark
size 1400 sq m.
date 2010

(fig 1.3)



(fig 2.1)

The Municipal Theater of Zafra is an innovative performing arts center. Among a typology associated with literal black-box theaters, the use of natural light here is unexpected and wonderful. Also significant is the urge to blend the distinction between public and private by openly allowing the public to engage with the building and observe ongoing activity. Some devices, like the pixelated eye mosaic on the stage seating, reminds the visitors of the public's presence. The program of the theater is not confined to theatrical performance. Rather, the Municipal


structure


geometry

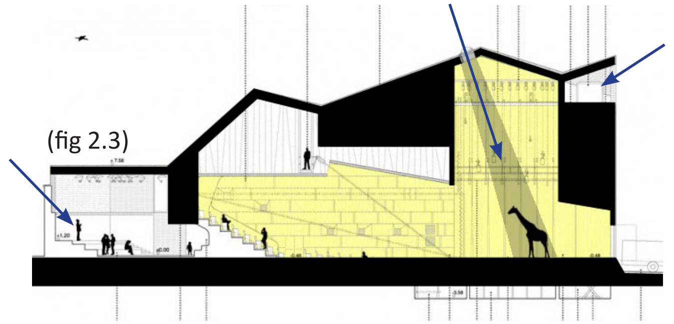
(fig 2.2)

Theater of Zafra retains a community connection by housing film, theater, orchestra, and acting as a concert hall. The strong use of vernacular materials and soft natural lighting gives the building a natural color pallet. Undulating sloped floors combined with patterns of natural lighting guide the citizens of Zafra through the program, encouraging participation with ongoing events or engagement with the building when no planned activity is happening.

Structure: The building's structure is comprised of concrete load bearing walls and a faceted, folded plate metal roof.

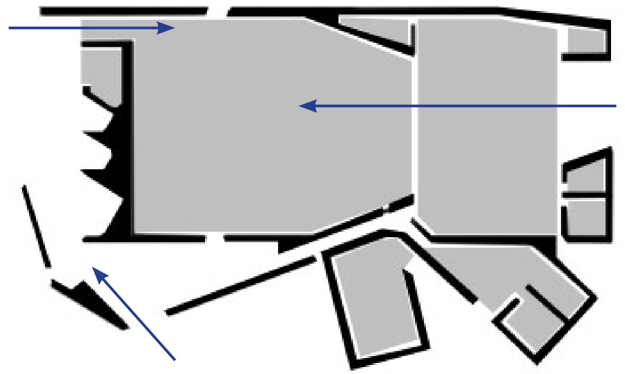
Geometry: The geometry of the structure and facade can be understood as a series of adjacent triangles and rectangles. The triangular elements are mainly used as roof structure.

Natural Light: The use of natural lighting within the space is an innovative feature of the building. Light is allowed through tiny skylight portals and a large opening filling the spaces with cool natural light and

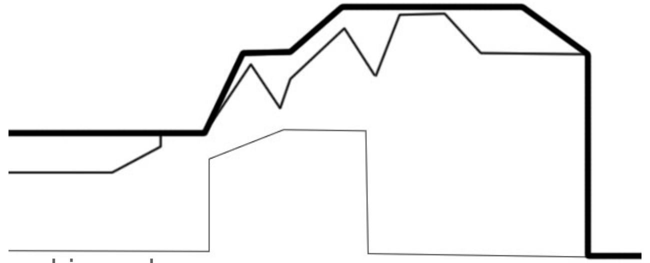


(fig 2.3)

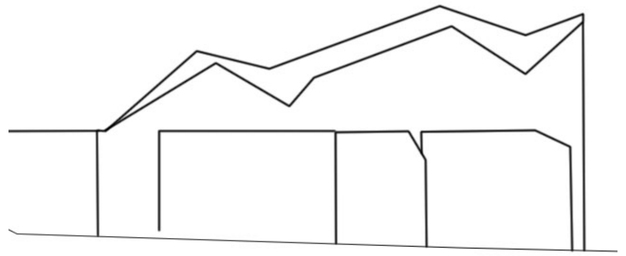
natural light



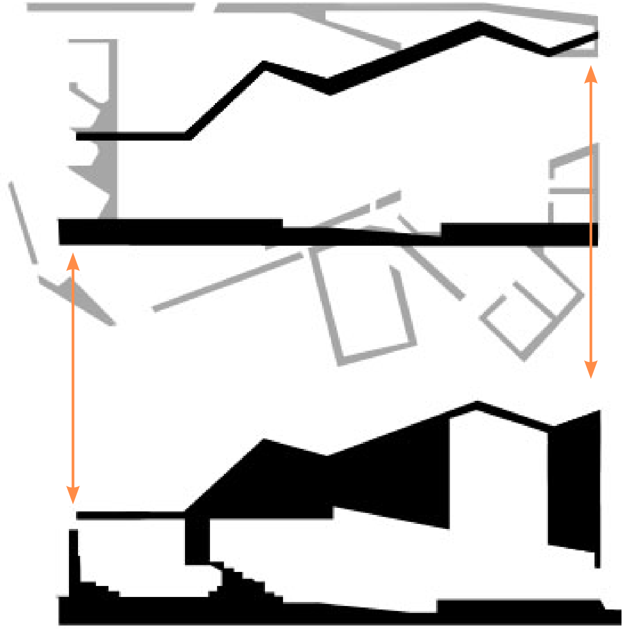
circulation



hierarchy



massing



section to plan

small piercing projections of light through the skylights.

Circulation: The circulation plan is typical to theater design with the exception of the loading dock's location and functional ability to transform the stage into an outdoor theater.

Hierarchy: The undulating roof plane is the strongest visual element, enclosing the exterior and terminating with the ground plane.

Massing: The massing reads as a series of two singular forms with subtracted components. The volume enclosing the stage is the dominant visual mass.

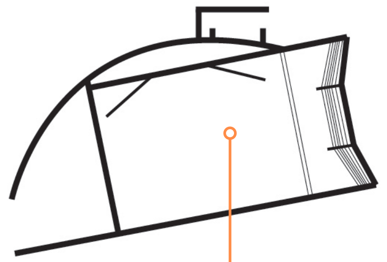
Section to Plan: Section to plan analysis reveals a rising plane enclosing the large space of the stage and backstage areas. The design language carries through in plan as faceted geometry terminating at the stage level.

Kinetic design furthers the flexibility of the space. A large opening behind the stage literally opens the theater to the community. This space doubles as the loading and unloading dock. When fully opened, the stage reverses to include an outdoor theater.

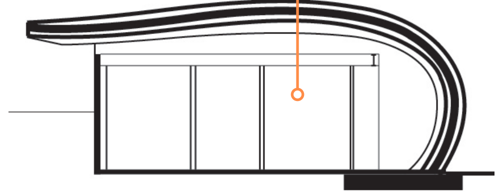
(fig 3.1)

The Wild Beast hosts several functions within a small footprint. A curvaceous shell houses acoustic cloud panels arranged like fish scales, projecting sounds inward for small rehearsals and practices. The large sliding panel at the south entrance serves multiple functions as either an interior partition or, when opened, transforms the space into a band shell. The Wild Beast can be quickly transformed from an intimate private recital room to an inviting pavilion.

The symbolic curve is inspired by the acoustic design principles of stringed instruments like guitars and violins. Structurally it is a highly efficient cantilever protruding from the ground, creating a spacious free span interior, which in turn allows a high degree of flexibility. Rotating panels both in the interior and exterior of the building assist the building in its pursuit of acoustic flexibility. Sound actuators located at the south clerestory are hinged and capable of opening outward. Rotating interior partitions swing outward carrying sound outdoors like a bandshell.

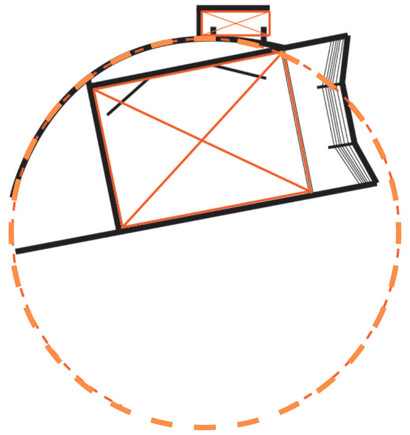


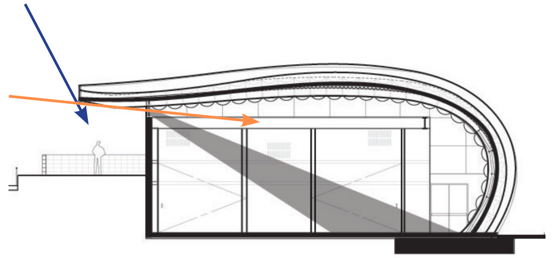
structure



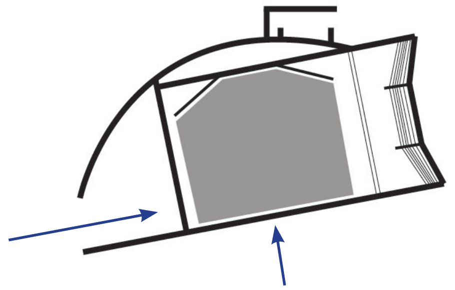
structure

geometry

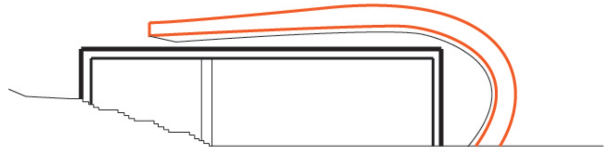




natural light (fig 3.2)



circulation



hierarchy

(fig 3.3)

Structure: The signature curve of the building visually encloses and contrasts with a white rectangle box. The primary interior space is a free span enclosed within the curved structure.

Geometry: In plan, the form of the building is a composition of rectangles with a large implied circle enclosing the rectilinear shapes.

Natural Light: The spacious open-plan interior receives an abundance of indirect natural lighting through its clerestory-style glass openings, and the large sliding panel blurs the line between indoor and outdoor space.

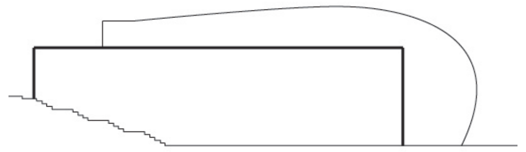
Circulation: Circulation within the building is comprised of two private side entrances and exits, and one large sliding entrance panel located at the south side, facing the courtyard.

Hierarchy: There is a three-tiered hierarchy composed of the curved roof, the strong rectilinear frame of the sliding exterior, and finally the intersecting ground plane establishing itself as a base.

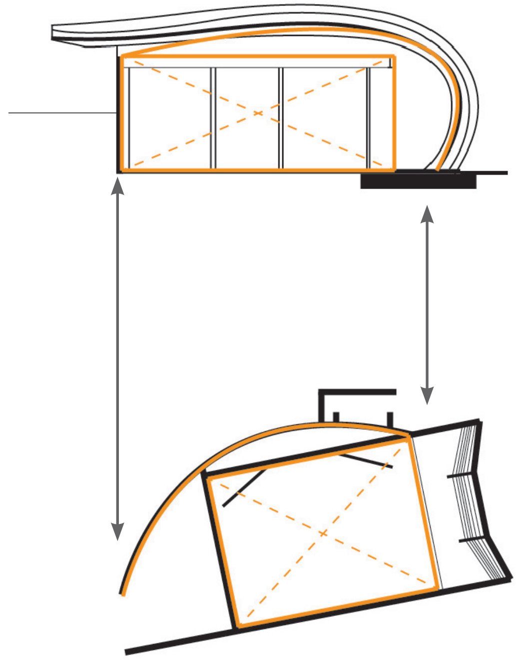
Massing: There are two distinct massing elements. A larger enclosing shell protects an implied rectangle composed of the sliding panels and structure frame.

Section to Plan: Plan-to-section analysis reveals the contrasted curved and rectilinear shapes as repeated elements. Scale, proportion, and location are dissimilar, but the language carries clearly through the design.

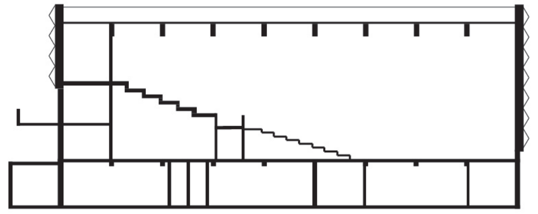
The shaded courtyard adjacent to the south sliding door can be used for casual spectator seating. Here, like the interior, the elimination of a fixed stage and seating elements offers several interchangeable options. The aviation-inspired sound actuators finely tune the sound for the audience.



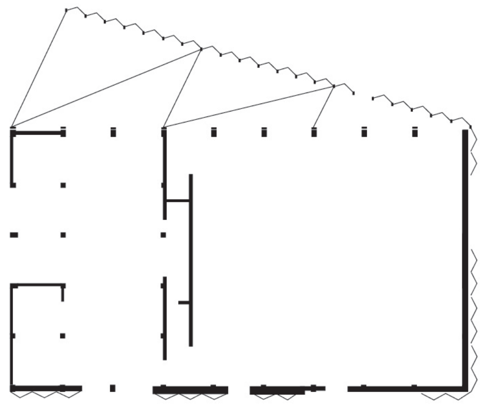
massing



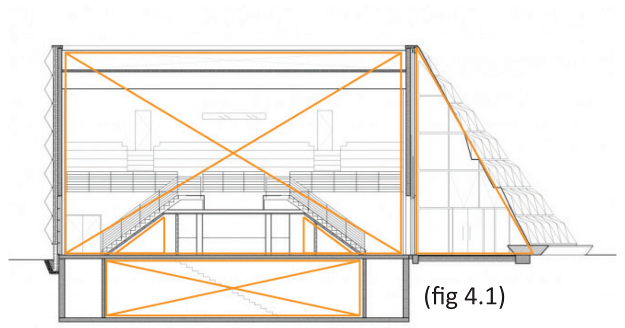
section to plan



structure



structure



(fig 4.1)

geometry

(fig 4.2)

Underneath the triangulated facade is the concrete shell of the original 1970s community theater. The new facade serves the building as both an energy efficient envelope enclosing the original structure and a public expansion housing a lobby, cafe, and a lounge. Operable gates separate the public and the light from entering the performance space when closed, and when opened transforms the ground floor into a bright, welcoming space. Red lights above the lounge area are turned on during performances, signalling to the community that a performances has just started. The facade composition is also theatrical in itself, resembling a curtain.

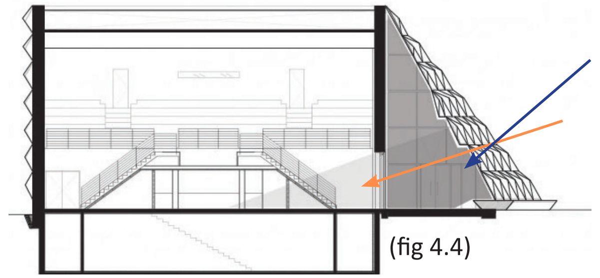
The prismatic acrylic exterior panels fade from opaque to varying degrees of translucency to clear, providing a spectacular play of lights both day and night. The new facade is appropriately scaled to the context (social housing) and offers a new degree of exposure and delight to the public by exposing inward activities to its citizens.

(fig 4.3)

Structure: The building's structure is a repurposed concrete shell covered by a triangular paneled exterior.

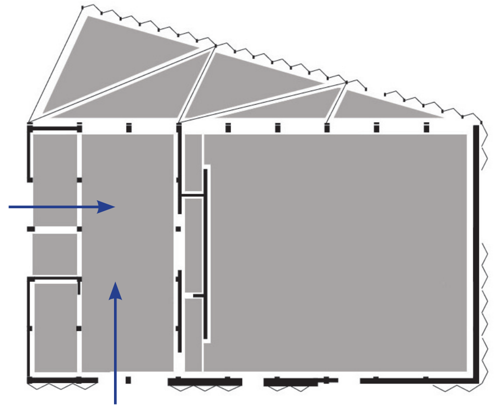
Geometry: The existing building is a series of well-proportioned rectangles inside the structural grid , with the new facade taking shape as a simple additive triangle.

Natural Light: Natural light abundantly passes through the translucent facade into the lounge and lobby of the building but does not penetrate into the theater. When closed the operable gates strengthen the feeling of privacy within the theater and provide a true black box theater.

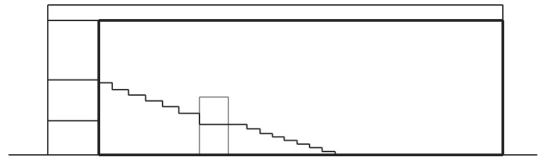


(fig 4.4)

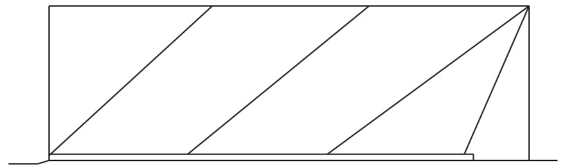
natural light



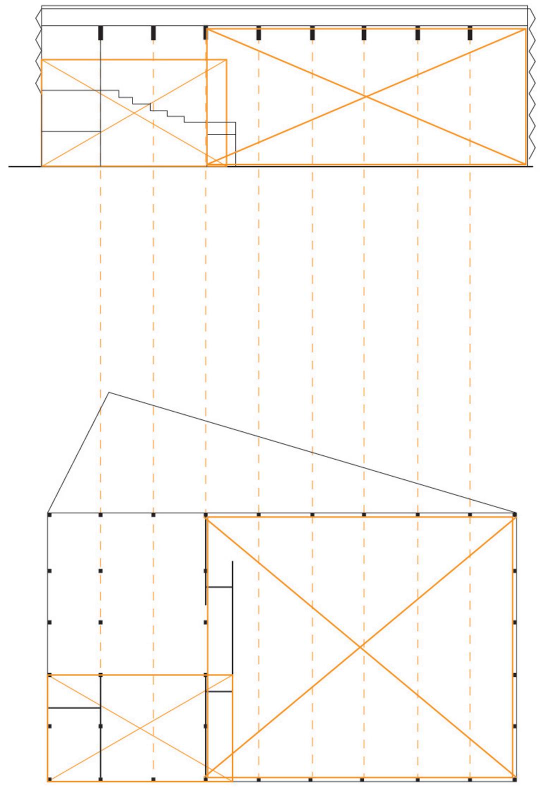
circulation



hierarchy



massing



section to plan

Circulation: The addition to the building functions as an entrance lobby and lounge space encountered before entering the theater. Private functions are moved to the basement of the building, creating an effective open first floor.

Hierarchy: In section the concrete shell of the existing structure has a strong visual emphasis, with the stepped theater seating forming a secondary element.

Massing: The building mass is easily read as a large rectangle with intersecting lines provided by the new facade.

Section to Plan: There is a strong structural grid and a series of similarly proportioned volumes enclosing space in plan and in section. The old structure retains a rigid symmetry in plan, while the new structure is playfully composed of symmetrical elements in section.

The new design exercises sensitivity to natural resources and energy use, keeping the old theater intact and simultaneously introducing an energy efficient skin. A highly efficient layout and private rooms moved to the basement result in a program easily staffed by a single person.

The theoretical premise and unifying idea are addressed uniquely by each of the projects studied.

The commonality between the three typological studies is the use of kinetic architectonic devices, increasing the flexibility of the respective designs. All three studies combine a highly efficient spatial layout with the ability to perform multiple functions within the same series of spaces. All designs exercise the use of passive systems and make use of efficient materials and structures. Another common factor is the use of direct and indirect natural lighting, illuminating space both as an efficient measure and an architectonic device.

The Wild Beast at CalArts impresses me as the greatest study of kinetic design. Multiple devices improve the design's flexibility, and in their absence the design would be reduced to performing a single function. The Beast's ability to adapt to changing circumstances directly addresses the theoretical premise and unifying idea. The design flexibility takes cues from traditional design solutions like the integrated site design and lack of fixed seating. It is, however, the pivoting, rotating, and hinged panels that provide this small building with its wide range of programs.

There are multiple lessons to learn from these studies, each of which could be enhanced through kinetic design. First, combine functions to make the most of a small footprint and utilization of space. Second, efficient structures and layout are key design factors. Finally, the artful use of controlled natural light is a necessary feature.

Performing Arts: Contemporary theater or performing arts design represents a clear shift in thought from the past. The genre draws both criticism and praise from a recent batch of popular architects stamping their respective signatures into the typology in the United States and across the globe. One thing is sure, theater is not dead (Minutillo, 2009).

Although performance art tries to remove any association with the performing arts, live performance is the shared factor that categorizes them as the plastic arts. This definition contrasts them with their counterpart, the visual arts, which is also referred to as the static arts. Live performance is defined by Weathersby in *Performing arts: the next stage* as "music, dance, and spoken word" and is the bond between performance and performing arts. (Weathersby, 2001; page 119).

Performance art categorizes the experimental, the grotesque, and the unusual. Esaak (n.d) describes the movement as a product of the 1960s, with roots stretching as far back as the Bauhaus in 1919. Although it is hard to define due to its animosity, Esaak describes it as "any live artistic event that included poets, musicians, film makers, etc...-in addition to the visual arts" (Essak).

Following the "poetry spouting" beatniks of the 1950s, performance art in the 1970s, included song and dance, autobiography, and brought attention to the popularity of body art, including self-mutilation (Essak). The 1980s to today's artists emphasize the experimental use of new media.

The newfound digital precedents of performance arts also play a role in contemporary theater and have huge implications on design. This current state of the live performance welcomes innovative buildings like the Wyly Theater in Dallas and the Starlight Theater in Illinois.

Kolleeny writes that Performing arts architecture is like storytelling, a text with a dramatic effect that contributes to the goal of heightening the imagination of theatergoers. She describes the Starlight Theater's unfolding, origami roof structure as a space modulator "opening and closing like the petals of daylilies" (Kolleeny, 2003; page 125). In another article, Kamin (2003) describes the Starlight's dramatic performance happening at the "click of a mouse... While patrons invariably look upward with a sense of wonder".

In Dallas, at the Wyly Theater, an elaborate system of winches and pulleys inspired by those in sports facilities and convention center transform not only the stage, but also the balcony seating. Dillon (2010) describing the technical wonder, writes, "Balconies fly up into the ceiling at the touch of a button; aisles can be rearranged between acts; the audience may sit on the floor at the beginning of a performance and on stage at the end".

New theater design is replacing the old not only for the technical wonder they can now achieve, but also as an economic function. Hart (2003) cites Russell Cooper, who says, "Few cities besides Washington, New York, and Los Angeles can support the single purpose, shoebox theater...The dollars are astronomical."

"Cities attuned to the benefits of the arts look for landmark architecture to make maximum impact"(Russell, 2005). This approach to architectural design, although credited for their economic benefit made famous by architect Frank Gehry (the Bilbao effect) does not belong to theatrical design amidst the current economic state. "States (Minnesota) have been especially brutal, sometimes all but zeroing-out support for arts in the face of looming deficits" (Russell, 2005).

In states like Minnesota community support needs to be provided. "For smaller cities that can't afford to build stand-alone facilities, universities can successfully merge town and gown" (Russell, 2005).

What remains then for theater design is flexibility and intimacy. Polyfunctional and tight budget projects like CalArts Wild Beast prove the feasibility of this recipe. Kinetic designs make possible an acoustic environment that can transform from a 140 seat recital hall to an 800 seat amphitheater. The future is smaller, more flexible, and kinetic. The future of theater design is adaptable to diverse scenarios and a broad range of users.

The Physical Context: The Minnetonka Center for Arts is a place for all people in the community to learn the visual arts from professional instructors with state-of-the-art equipment and facilities. They offer unique courses that are not available in most educational facilities. The Center for the Arts is well regarded by the community and has been a thriving non-profit since 1952. Currently there are no facilities for the performing arts.

My senior Student Art invitational was held at the Minnetonka Center for Arts in lieu of my high school's lack of facilities to do so. In doing so, The Center for Arts addresses the viability of Russell's model for shared economic support. The trade-off brings equality to the arts community, providing talented individuals the resources their schools cannot provide.

the following are my academic, professional, and personal goals for the duration of the design thesis process:

Develop a theoretical premise and project emphasis that interests me and bears importance to my past, present and future.

Provide a thought-provoking and easily understood statement of intent.

Complete all material at a proficient pace to avoid rushing deadlines and submitting incomplete information.

Continue the development of my personal design methodology through practice and experimentation.

Demonstrate a holistic understanding of architecture (theoretical, structural, mechanical, and experiential).

Deliver a well-detailed and complete project at the highest quality I am capable of producing.

Create visually compelling and easy-to-read graphic communication that provides sufficient information to the understanding of the project.

The journey to the site is made by car, following slow, winding roads and passing the bays of Lake Minnetonka. Approaching either from the east or west requires drivers to slow down as they leave traffic and enter a quiet, local, paved road. A tree canopy is the first greeting marking proximity to the site.

Arrival to the location is marked by the sudden clearing that follows and catching a sight of the clean and modern Minnetonka Center for Arts campus sitting across from the site. An open field is covered by a blanket of tall prairie grasses. Its presence is calm, relaxing, and very stark. There is no human presence on the site and there was very little surrounding it at the time of my visit.

Although it was cold and cloudy during the visit, strolling through the tall grasses was very pleasant. There were no sounds other than an occasional passing car and the rustle of grass and leaves swaying in the cool southern breeze. The nautical atmosphere of the lake and my experience at the site felt like a great escape form the suburban residential surroundings.

Dichotomy best describes the results of further exploration around the perimeter and hiking through the grasses. Although within its borders the site is

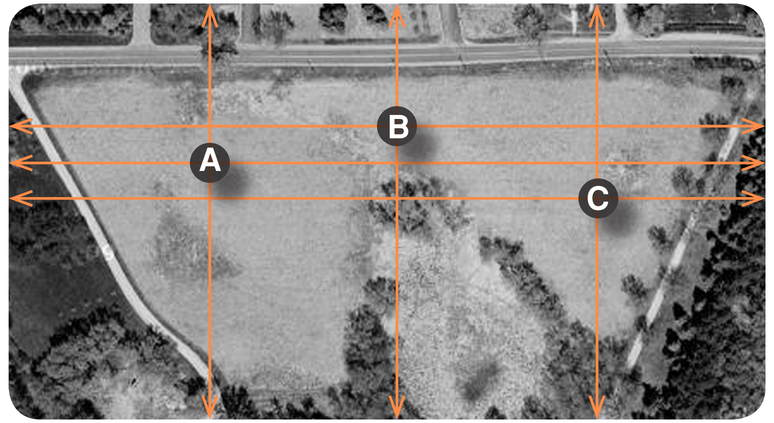
Above: Location B - view north

Below: Location A - view south

self contained and very stark, there are signs of life everywhere. Power lines, roads and driveways, garbage in the ditch, and the distress of the built environment show the signs of human presence. Meanwhile dead trees, animal tracks, and the natural decay of an old stone wall show the forces of nature.

There is a further dichotomy of the old and the new, of visual from and emptiness, of vernacular design and postmodernism. Though it was unusual to document such contrasting elements, after I left the site I realized how perfect it really was. That little field in the center of suburban sprawl represents an oasis. This will be a place to escape the busy world and be transformed by the wonderful world of art and the beauty of the natural.

(site reconnaissance photos were taken at the locations below, facing the four cardinal directions)



topics below represent an area of analysis

Distress: Broken windows, decaying buildings, and a weathered stone wall. Natural distress is evident in the built features found around the site.

Lighting Quality: At the time of the visit the lighting was very diffused by the cloudy sky and had a strong gray hue.

Wind: Two buildings at the north of the site provide minimal wind block. A border of trees around the south edge provides a strong block from any northern winds assisted by the lake effect. The east and west are protected by the same border of trees. Due to microclimatic conditions, observed wind direction is different than the prevailing winds prediction.

Site Character: The site has a few dead trees, animal tracks, and occasional traces of litter. The dominant feature is the tall golden prairie grasses occupying the site.

Human Characteristics: There are few apparent signs of human use at the site. Human intervention is evidenced in the built environment bordering all edges of the site. For example, this a residential driveway bordering the west edge.

Above: Location C - view west

Below: Location A - view east

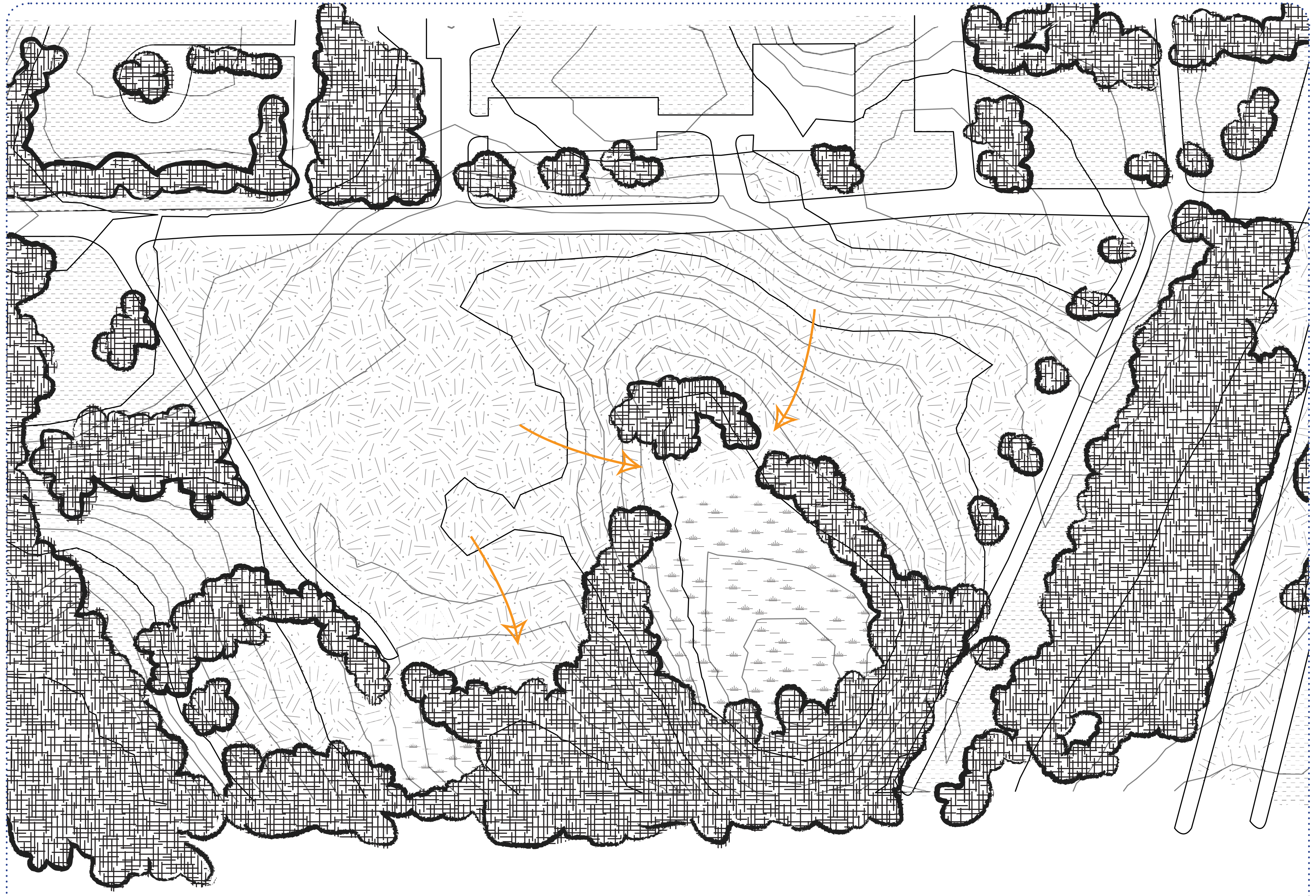
Textures: Strong tree canopies and tall grasses are dominant material textures. The paved roads and parking lots contrast the natural elements but do not dominate with their presence.

Slope Calculation: Slopes across the site never exceed 12 percent grade. A majority of the site, nearly 73%, has a slope between 0 and 6 percent. This is an easy grade to build on, and easy for casual pedestrian movement.

Slope & Climate: There is no steep slope on the site. There is a marginal slope at the south border receding into marsh. There was no noticeable water during the visit.

Shading & Shadows: The north of the site is fully exposed to indirect northern sunlight. The east and west borders are formed by a tree line which will provide shade during sunrise and sunset and especially during winter months when the sun has the lowest altitude.

Topography & Air Movement: On the buildable areas of the site, topogrpahy has no immediate impact on the movement of air. The lake breezes have no apparent effect as the site is well-protected by tree cover.



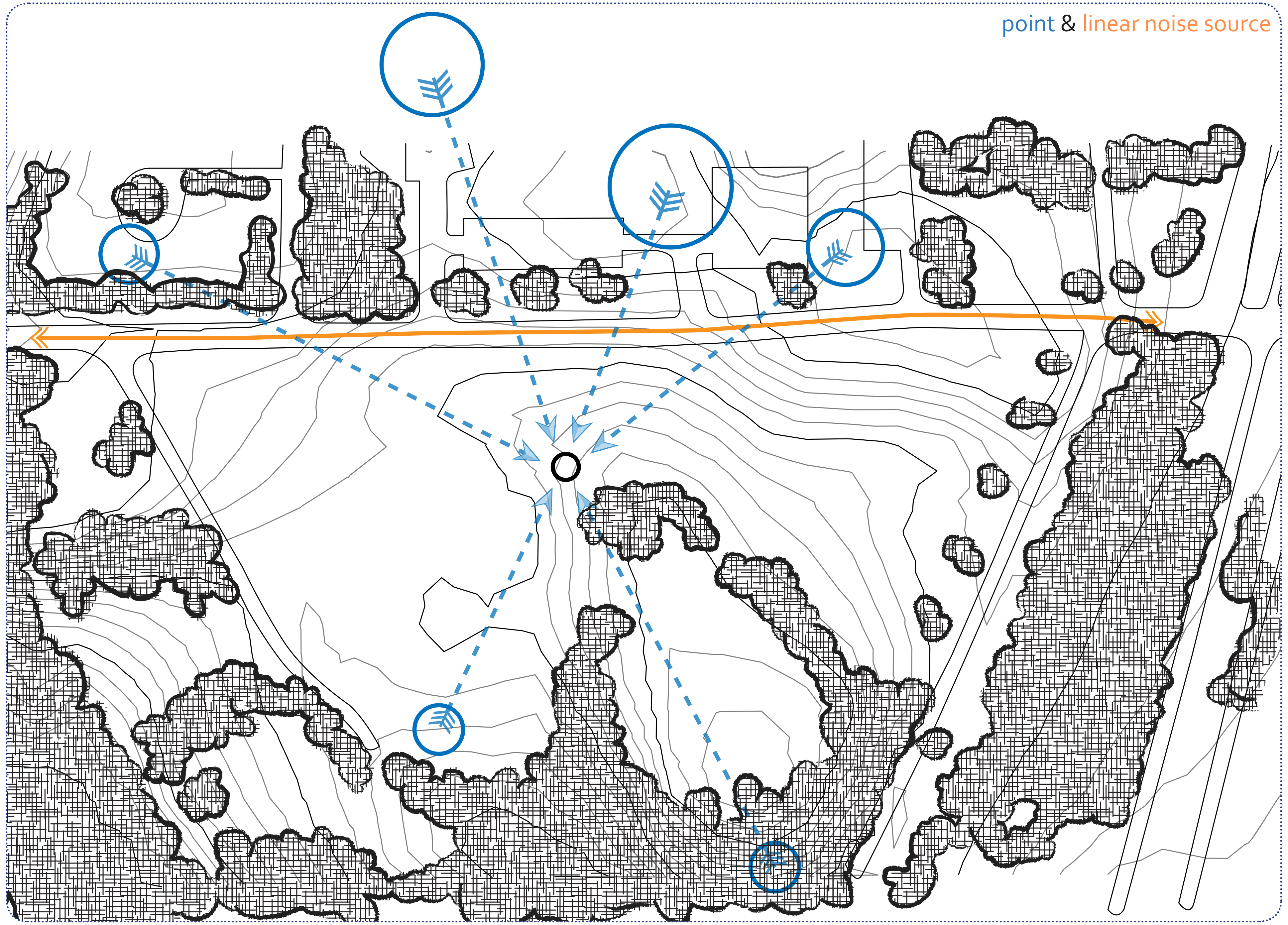
dense tree cover - tall grass - mowed grass - swamp conditions - drainage

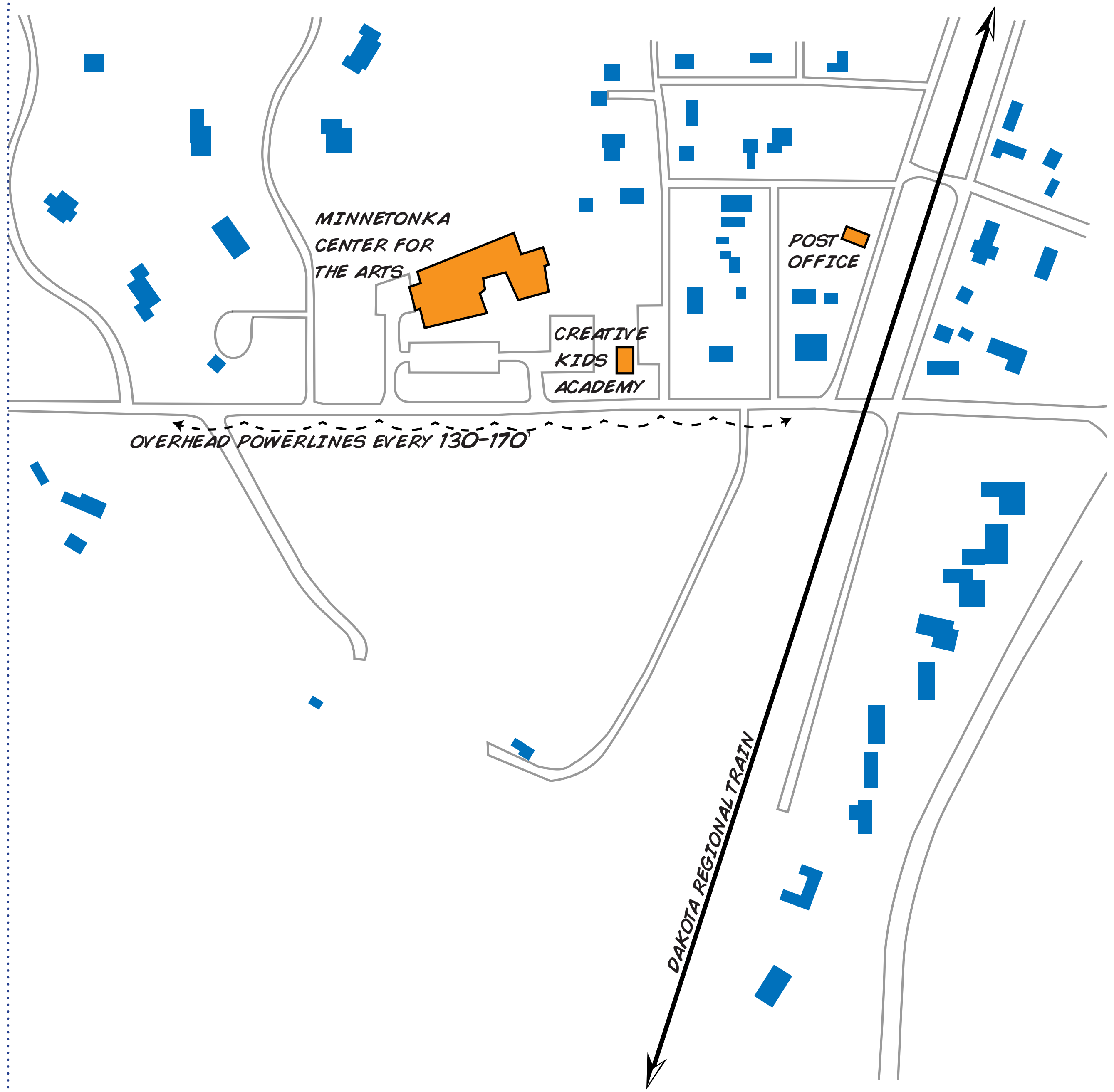
figure & ground study

Noise: Noise is primarily generated from the road bordering the northern edge of the site. Secondary sources of noise are generated from the Center for Arts, the school adjacent to the Center for Arts campus, and the surrounding residential neighborhood.

Existing Grids: The built environment has developed in a grid to the north of the site. Roads frame buildings. Lower traffic roads and parking lots are formed from a rough grid of the main road.

Geometries: The built forms of the Center for Arts campus are well-proportioned volumes with strong geometric relationships to each other. With the exception of the school houses, all other built features are hidden by tree cover.





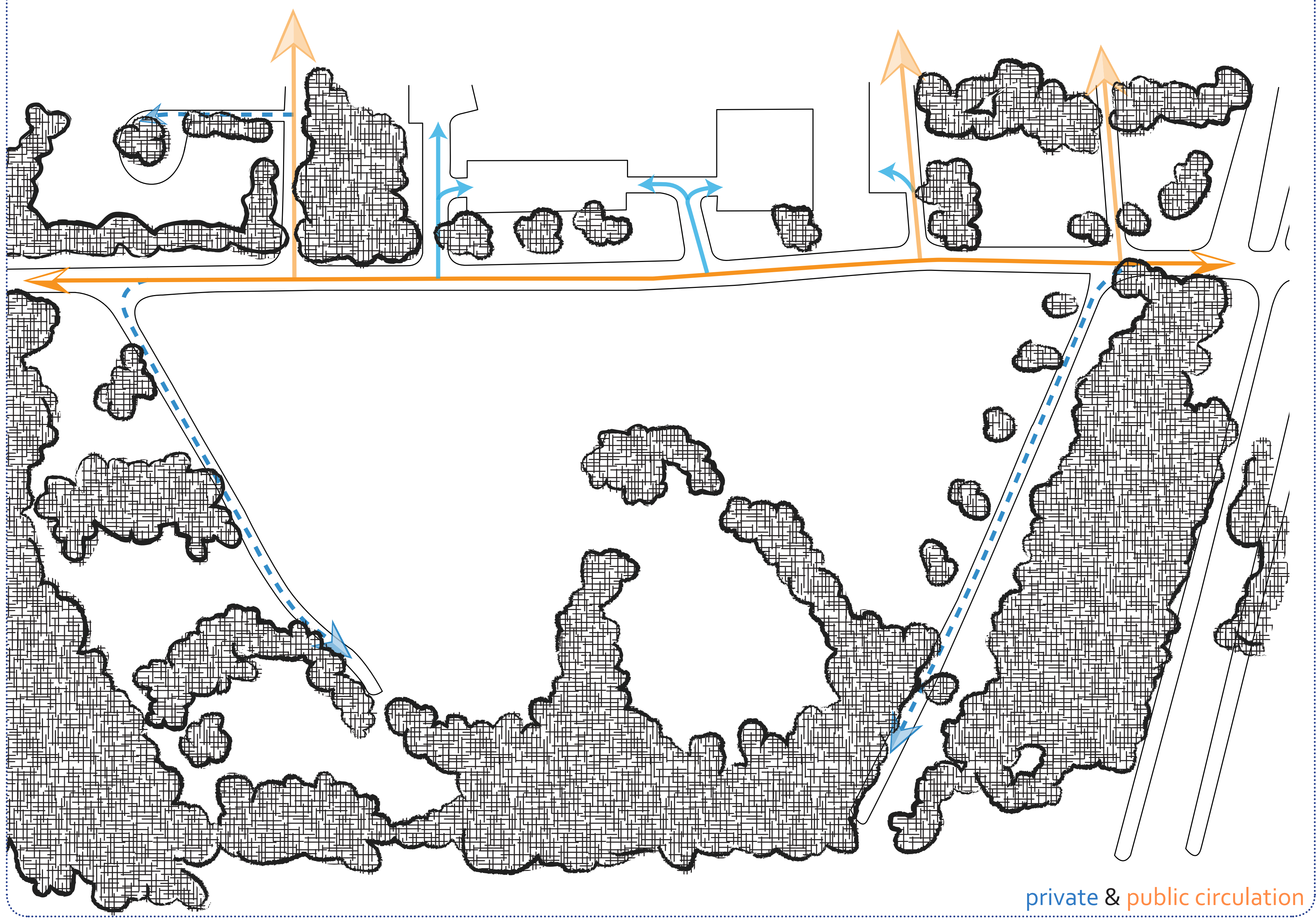
residential & commercial buildings

Built Features: The Minnetonka Center for Arts and the Creative Kids Academy are the two most prominent built features neighboring the site.

Utilities: Overheard power-lines run parallel to North Shore Drive at the north edge of the site.

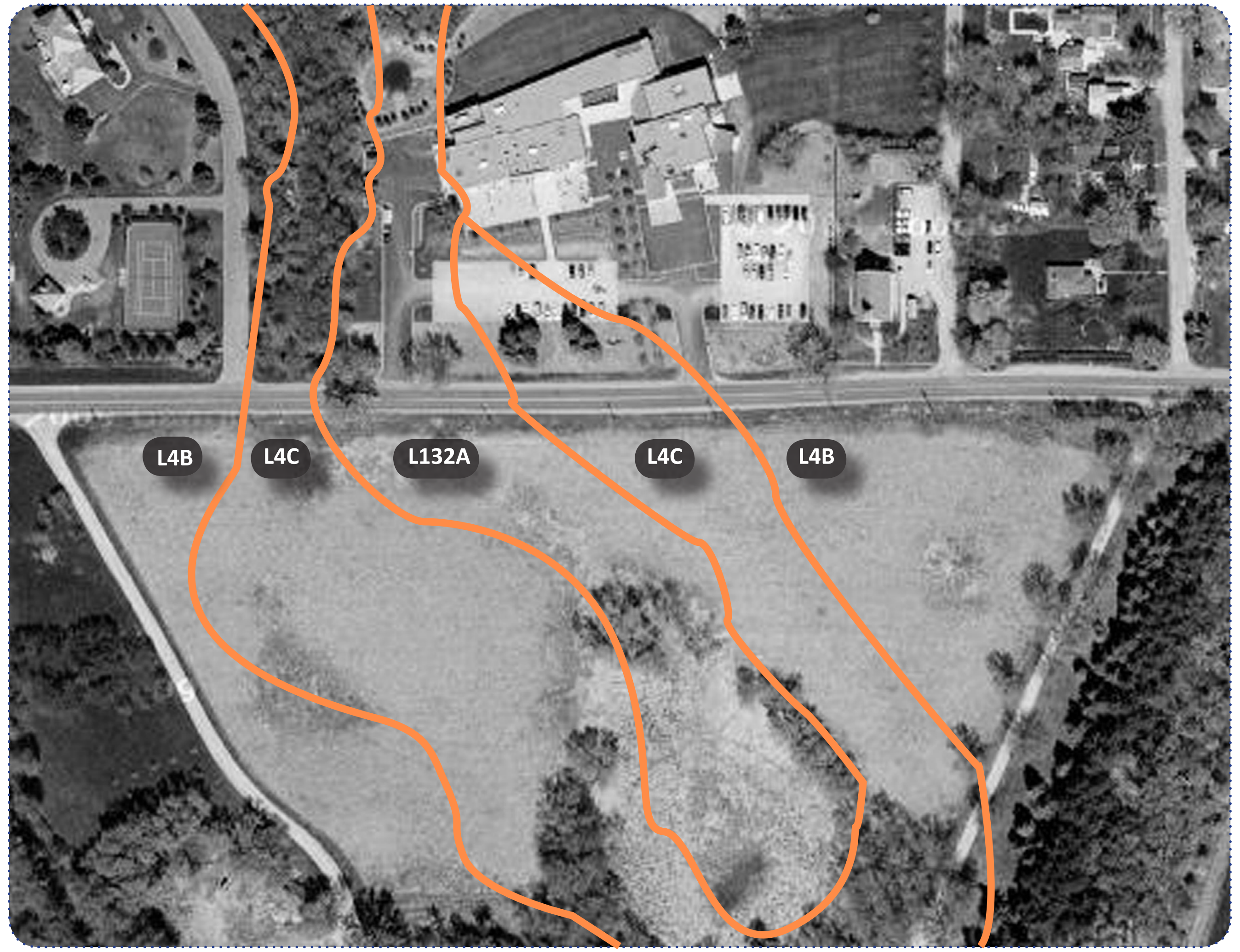
Pedestrian Traffic: The Dakota Regional Trail is frequently used by bikers and walkers during the summer. There is no sign of human traffic on the actual site.

Vehicular Traffic: There is a low traffic volume along the two-lane stretch of paved road, and a shared driveway on the east edge of the property.



private & public circulation

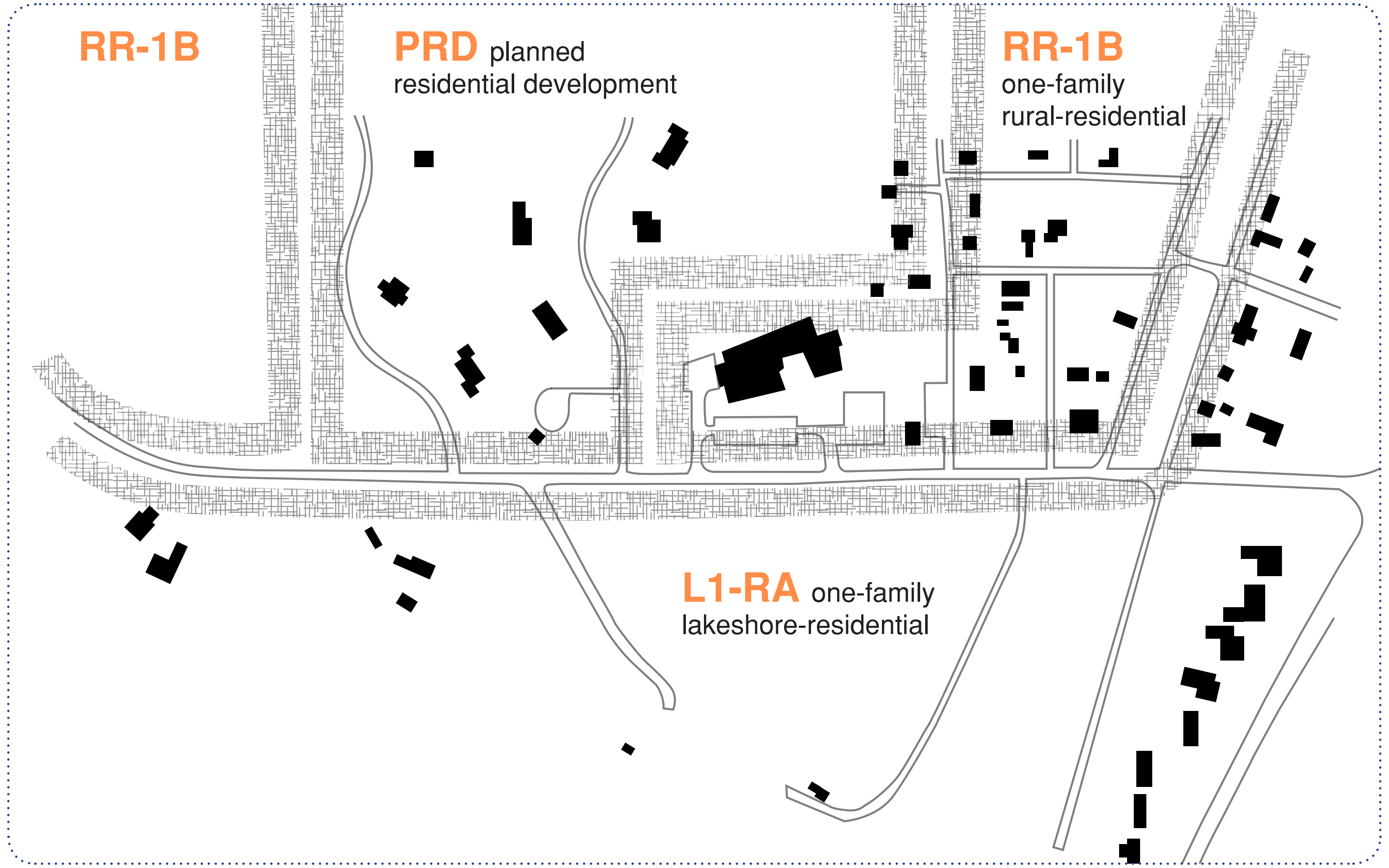
Rain Garden: This element, found across the street from the site location, is a rain garden collecting runoff from the parking lots at the Minnetonka Center for the Arts. Its strong visual axis will play a strong role in the identity and site design of the the performing arts center.

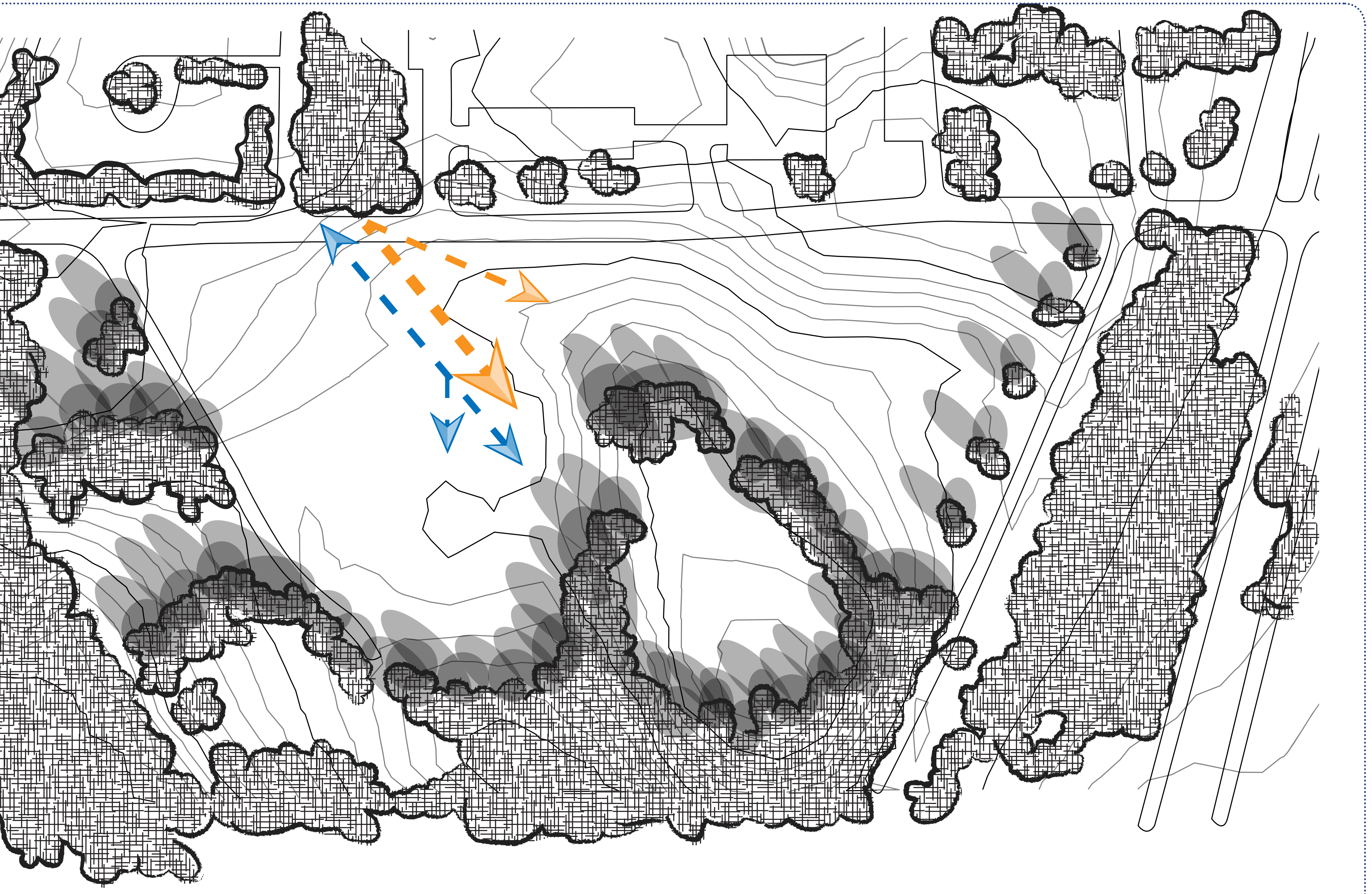


L4B: Crowfork loamy sand, 1 to 6 percent slopes, occupies 25.0 acres, 66.8% area of analysis

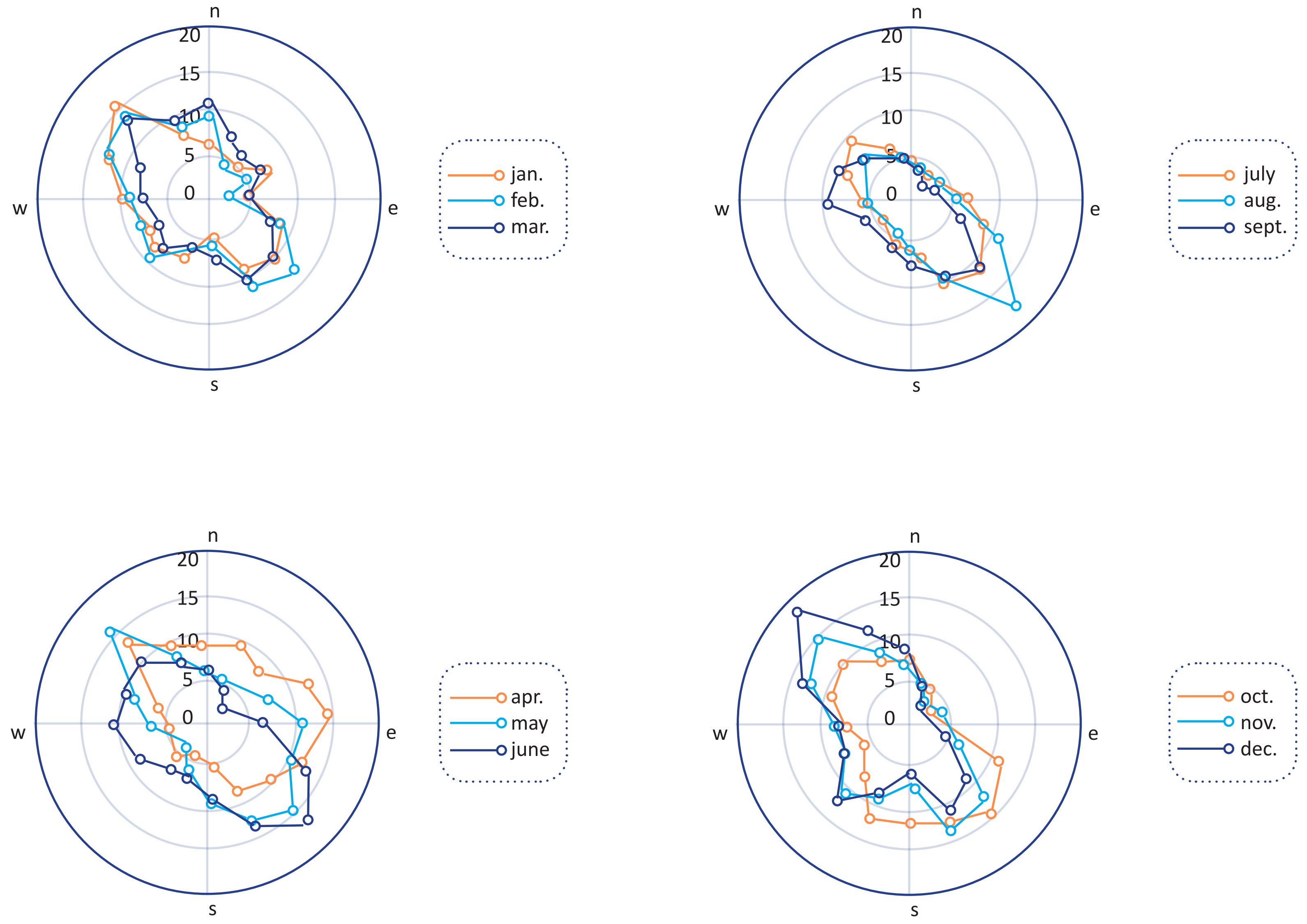
L4C: Crowfork loamy sand, 6 to 12 percent slopes, occupies 7.9 acres, 21.1% area of analysis

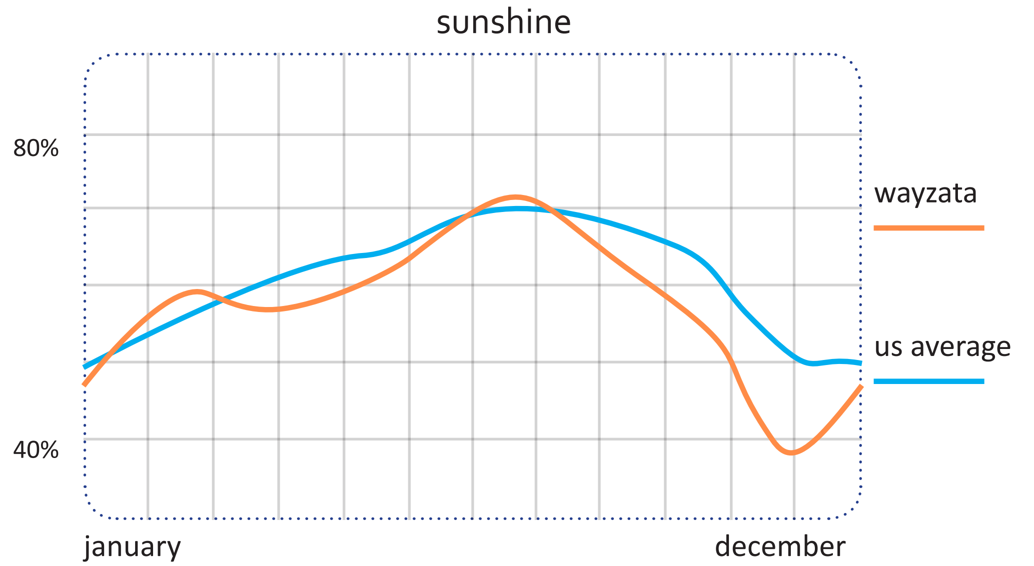
L132A: Hamel-Glencoe, depressional, complex, 0 to 3 percent slopes, occupies 4.1 acres, 10.8 % area of analysis

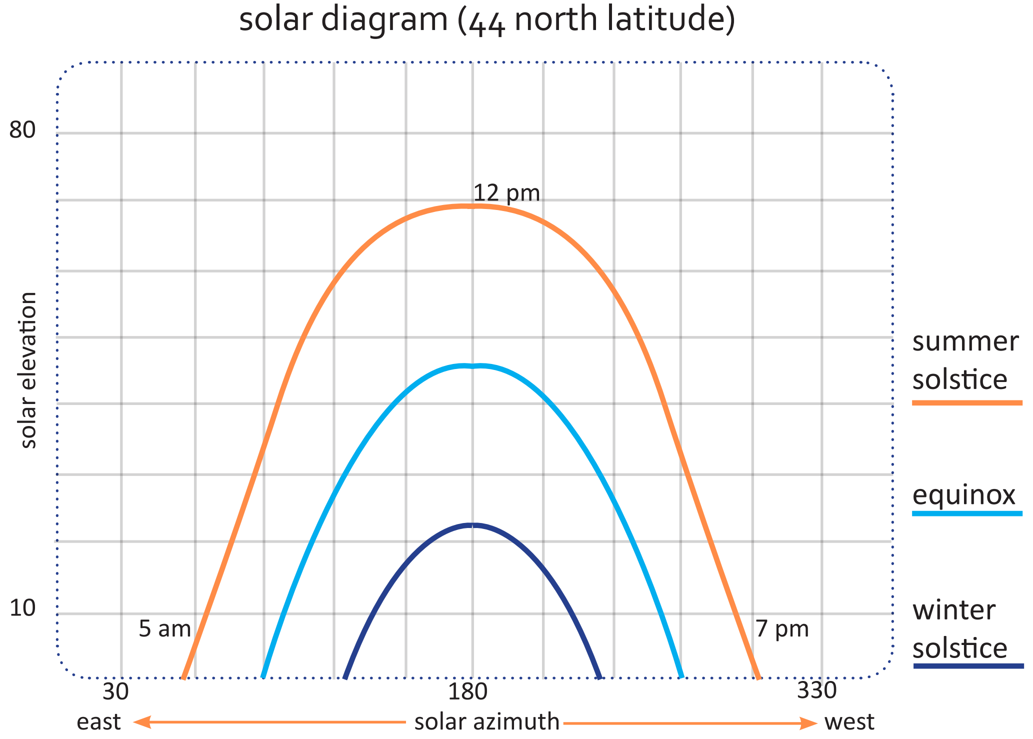


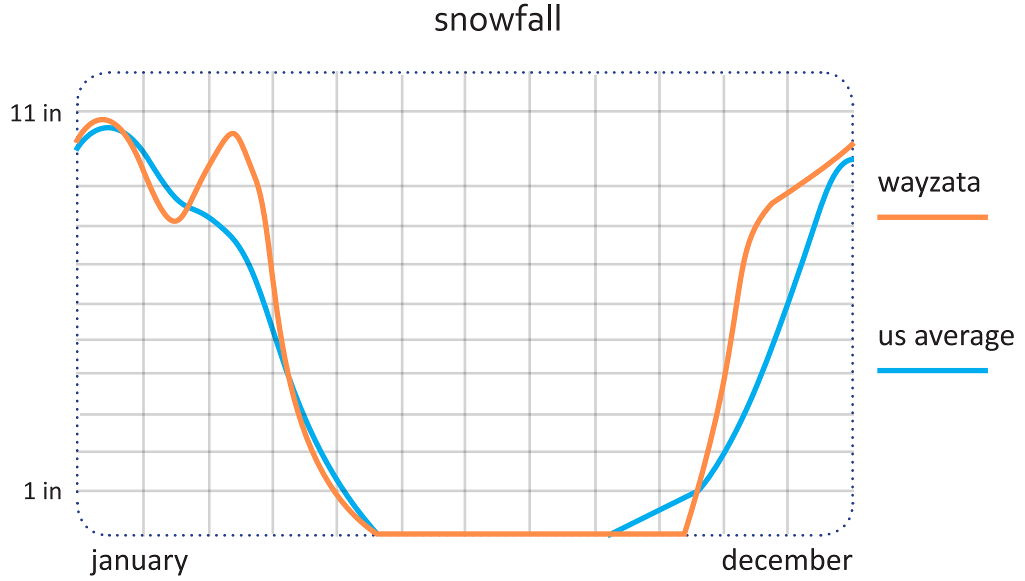


summer & winter winds - shadow coverage




sunshine
80%
40%
january
december
wayzata
us average


solar diagram (44 north latitude)
80
10
solar elevation
12 pm
5 am
7 pm
30
180
330
east
solar azimuth
west
summer solstice
equinox
winter solstice


snowfall
11 in
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january
december
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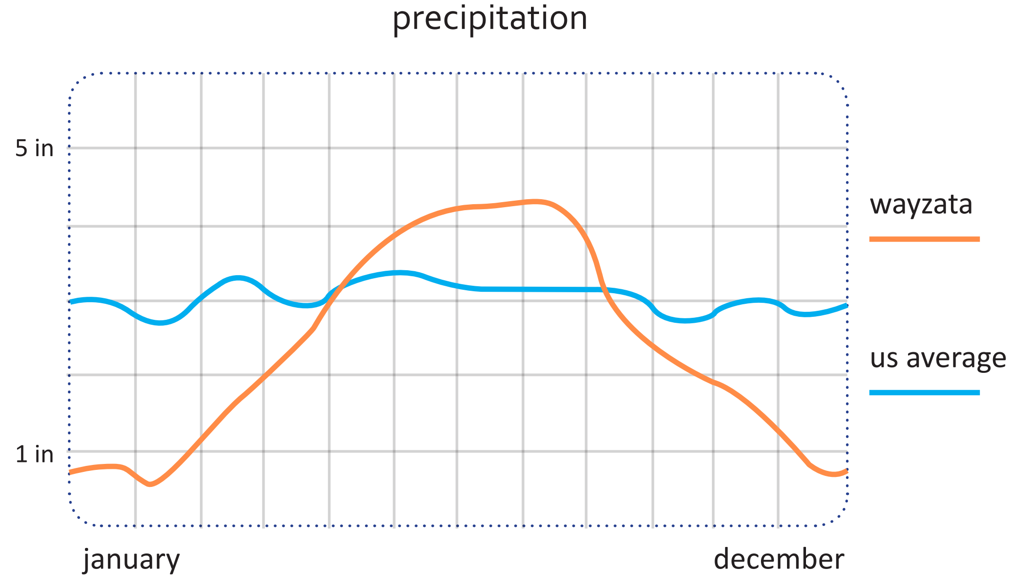
precipitation
5 in
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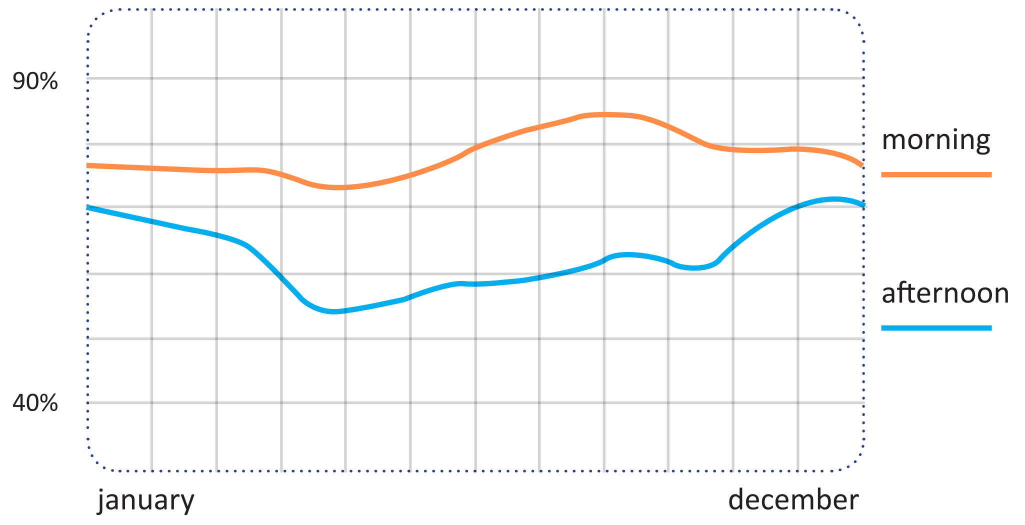
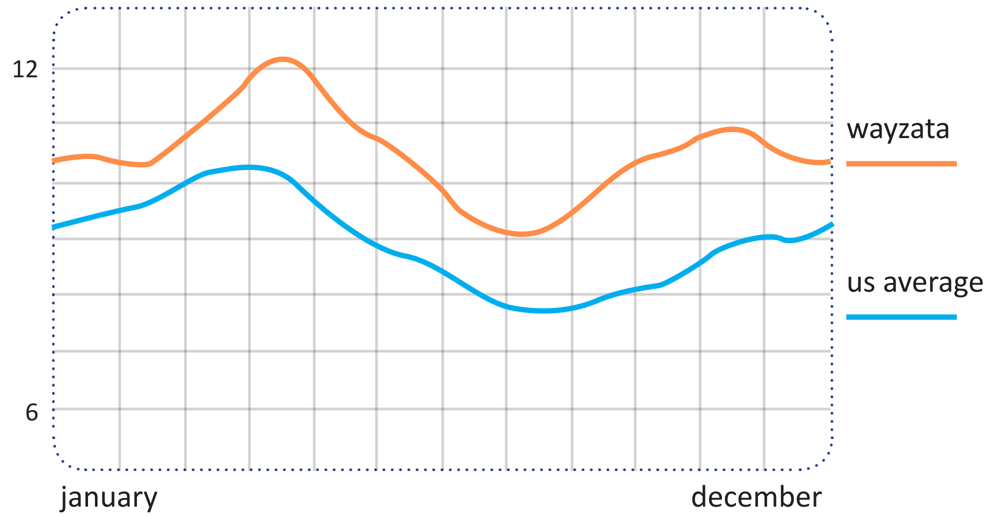
december
wayzata
us average

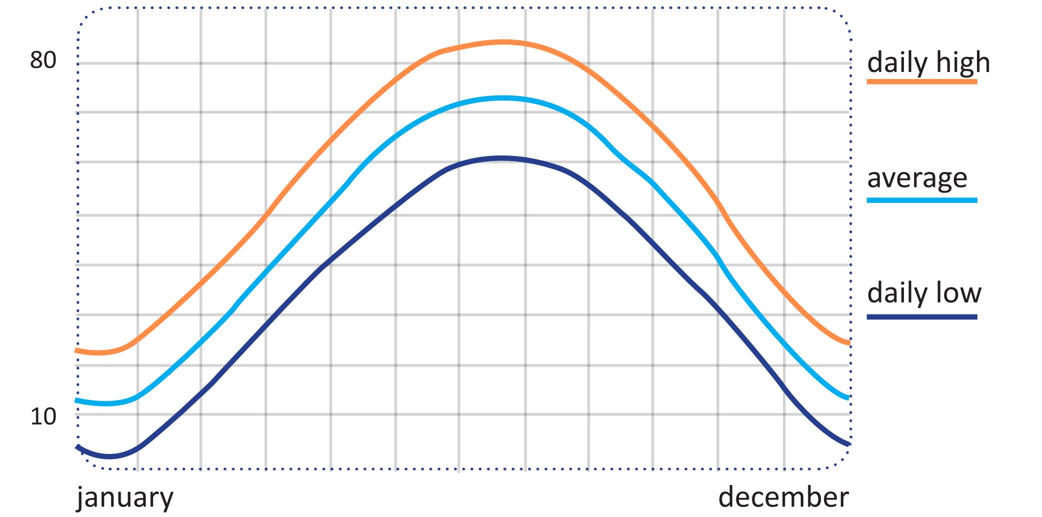
humidity



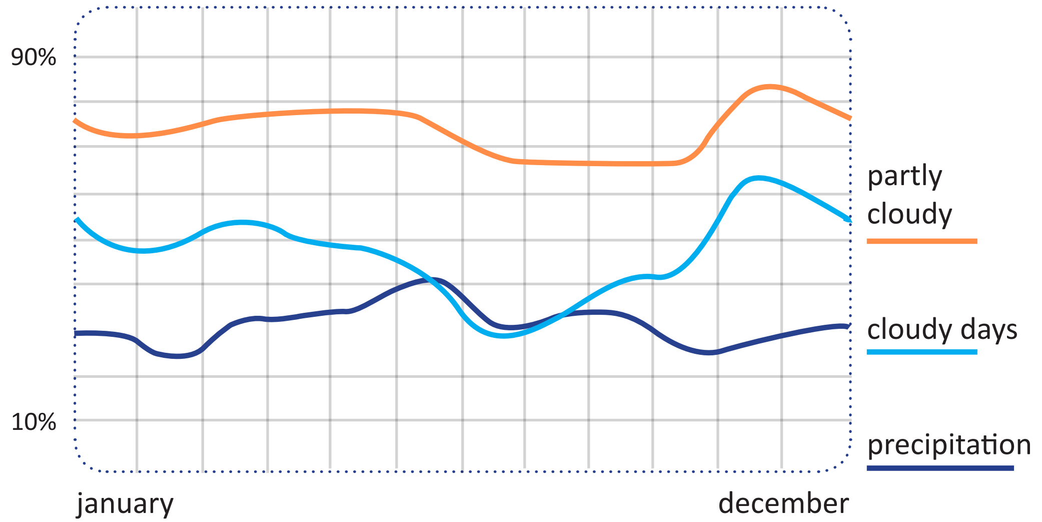
wind speed (mph)



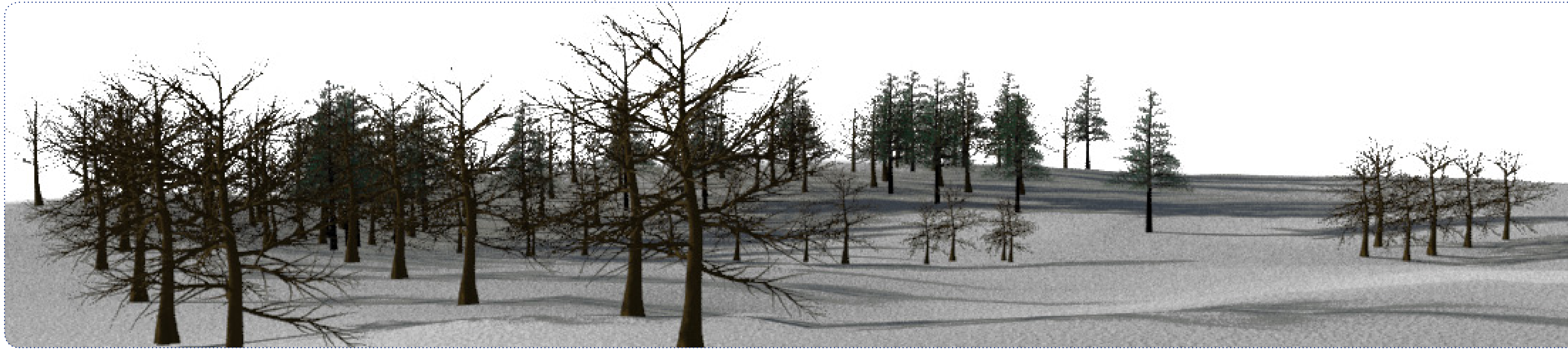
average tempreatures



cloudy days



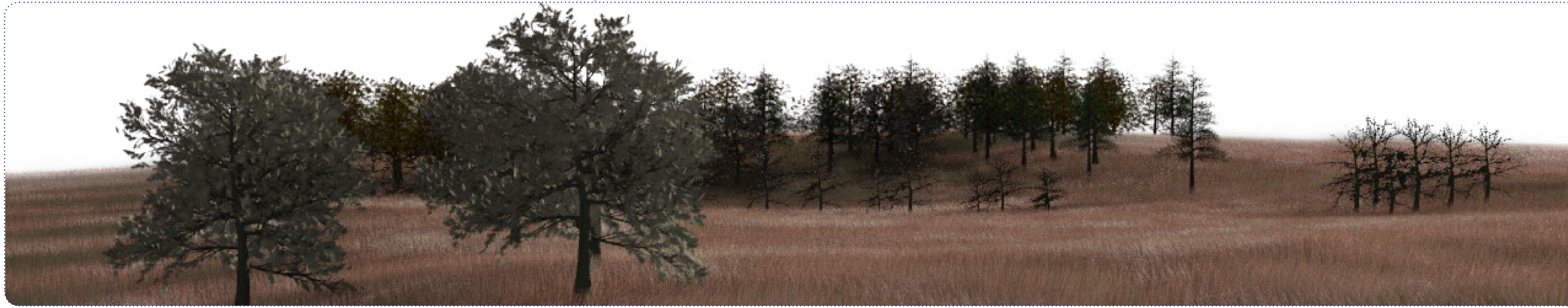
further site analysis investigating the relationship of landform and shadow coverage with the desired building locations. the site was constructed as a three-dimensional model in 3ds max and rendered at different times of the year.



Above: A winter morning solstice. This is the time of the year the sun is lowest in the sky, and the shadows are the longest.

Right: A summer evening solstice. At this time of year the sun is highest in the sky.

In both images, it is clear that landform does not affect shadow patterns. Only the dense tree cover skirting the site produces shadows across the site.



technical

projection
100 sq. ft. total

sound & light
150 sq. ft. total

video
100 sq. ft.

electrical closet
200 sq. ft.

performance

stage
1000 sq. ft.

backstage
750 sq. ft.

audience
10. sq. ft. x person
175 seats
1750 sq. ft. total

support

changing rooms
men's & women's
400 sq. ft. each

locker room
instruments
400 sq. ft.

rehearsal studio
1000 sq. ft. each
2000 sq. ft. total

set & storage
1000 sq. ft.

maintenance
250 sq. ft.

loading dock
200 sq. ft.

office

teachers' offices
100 sq. ft. each
400 sq. ft. total

conference room
150 sq. ft.

breakroom
100 sq. ft.

bathroom
men's & women's
100 sq. ft. each
200 sq ft total

mail
150 sq. ft.

public

bathrooms
men's & women's
300 sq. ft each
600 sq. ft. total

lobby & lounge
10 sq. ft. x person
175 people
1750 sq. ft. total

reception
150 sq. ft.

courtyard
3000 sq. ft.

vestibule
100 sq. ft

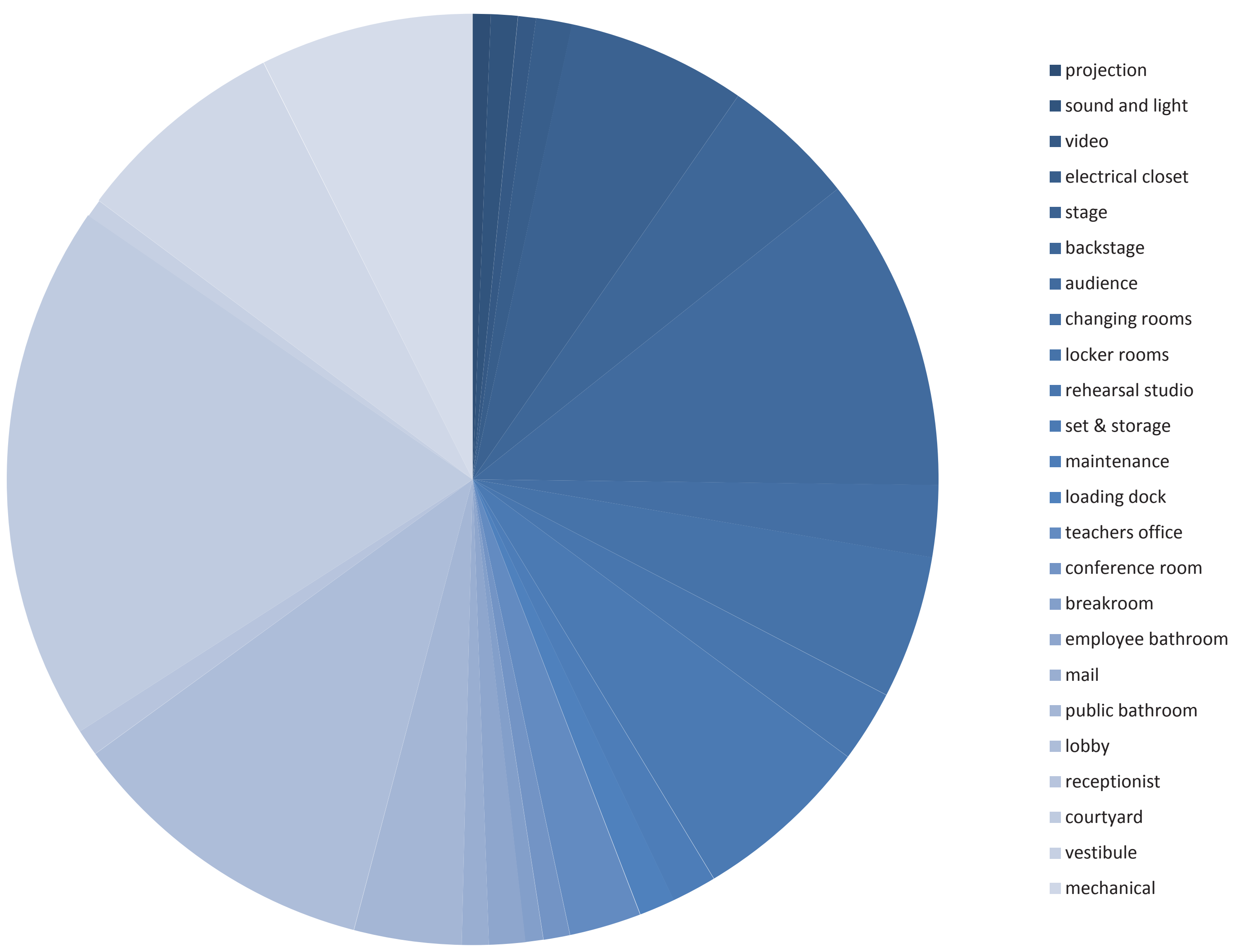
public
private
performance

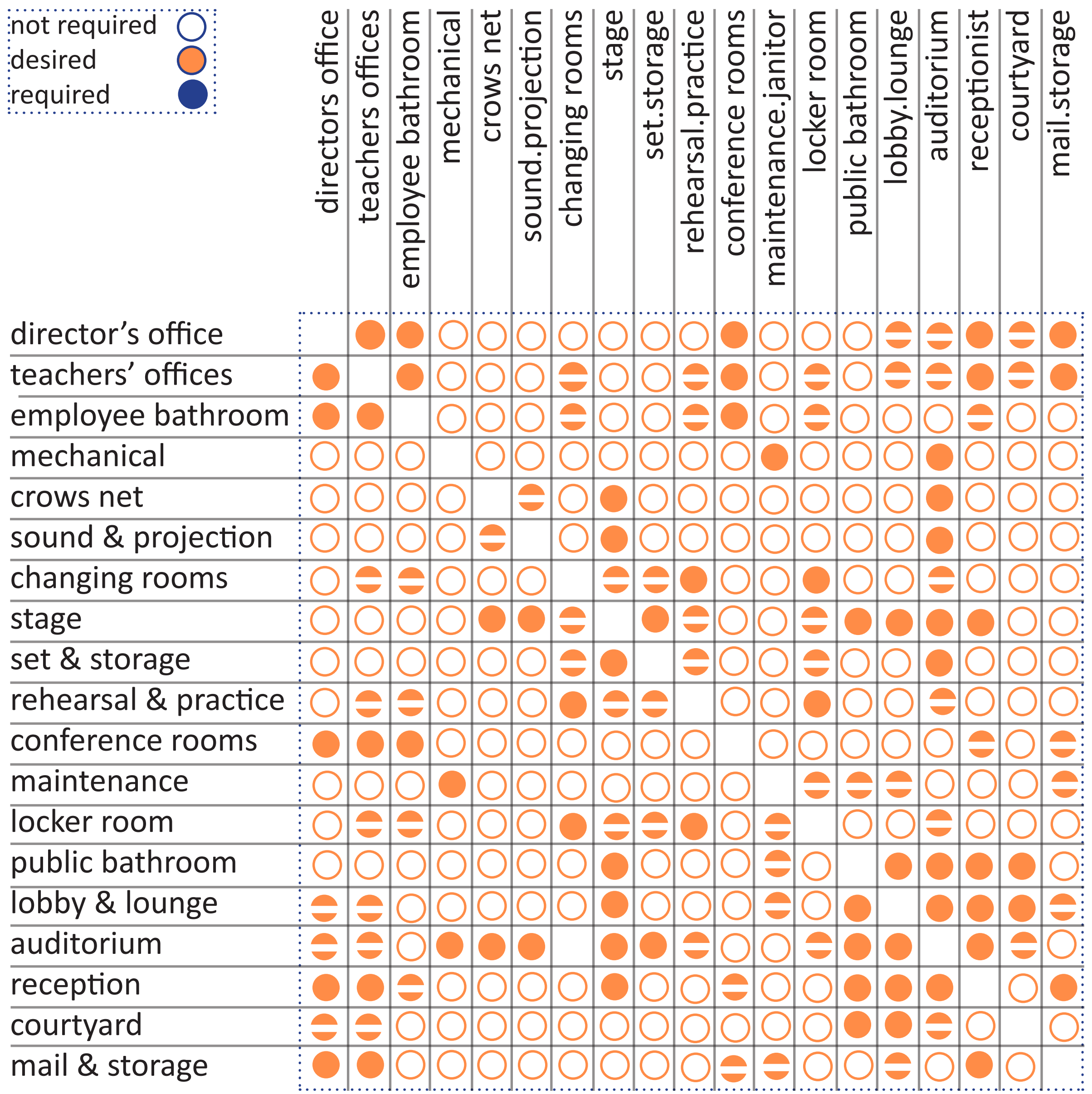
14,900 total
sq. ft.

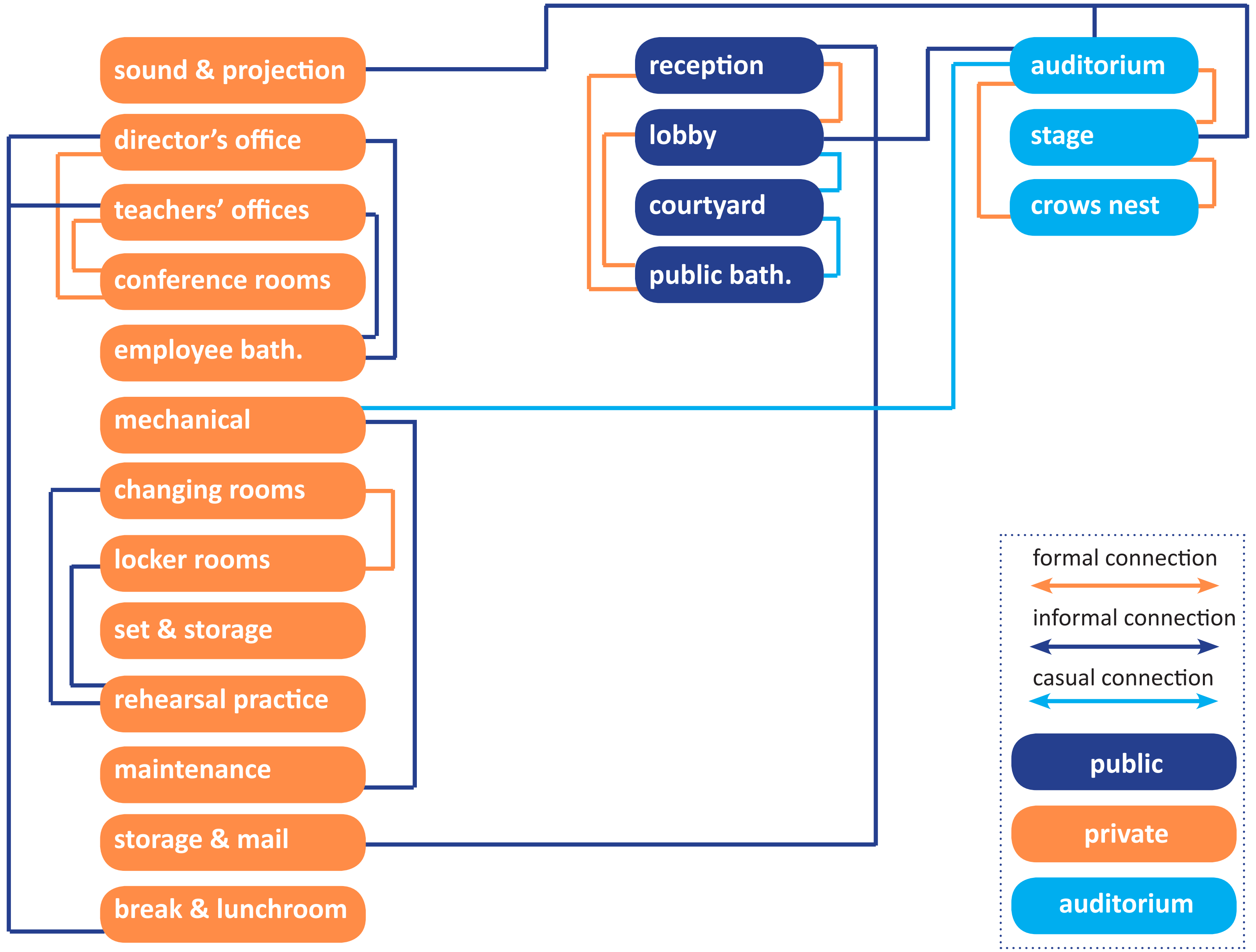
mechanical
10% of total
1,190 sq. ft.

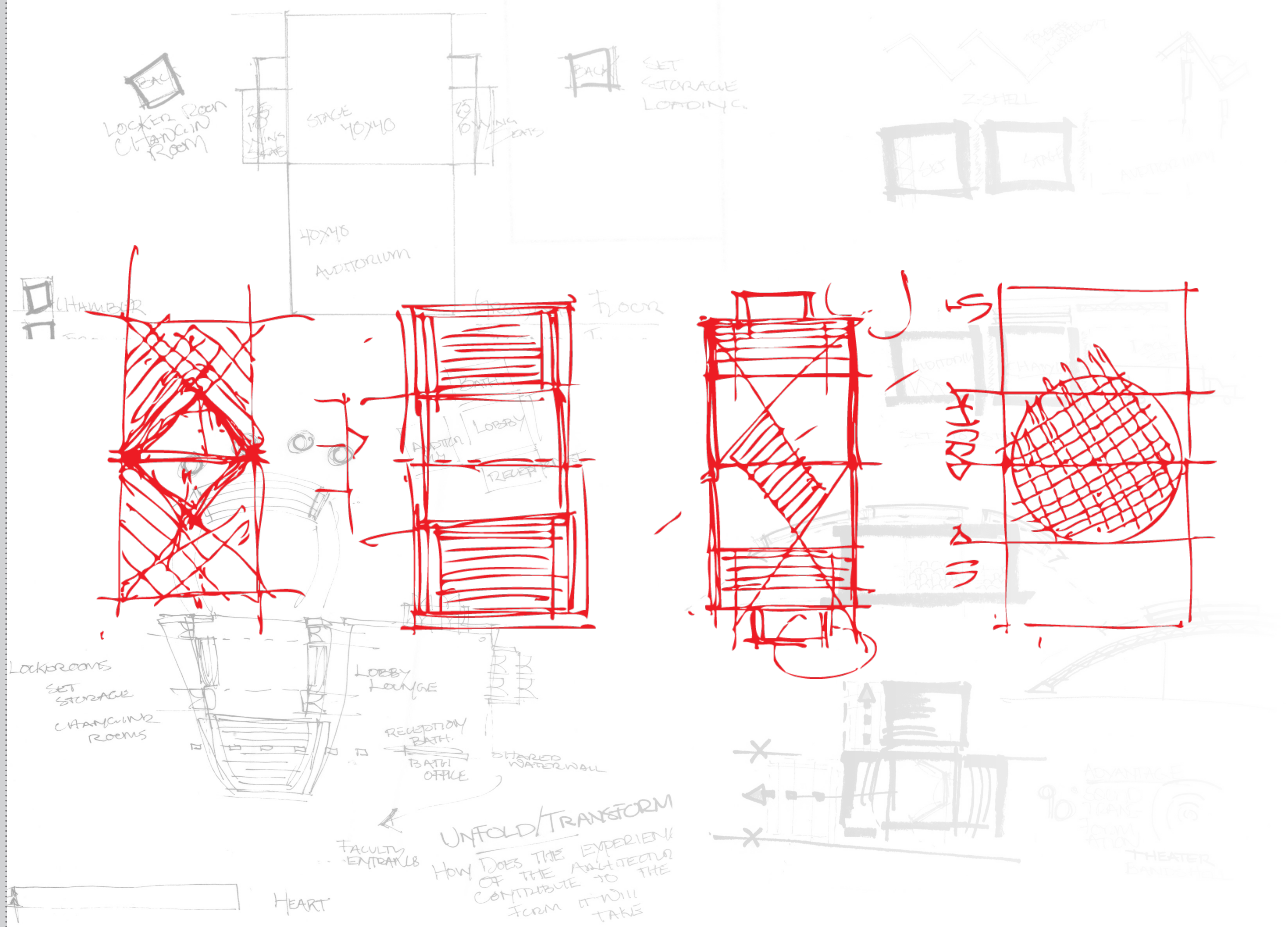
circulation
10% of total
1,190 sq.ft.

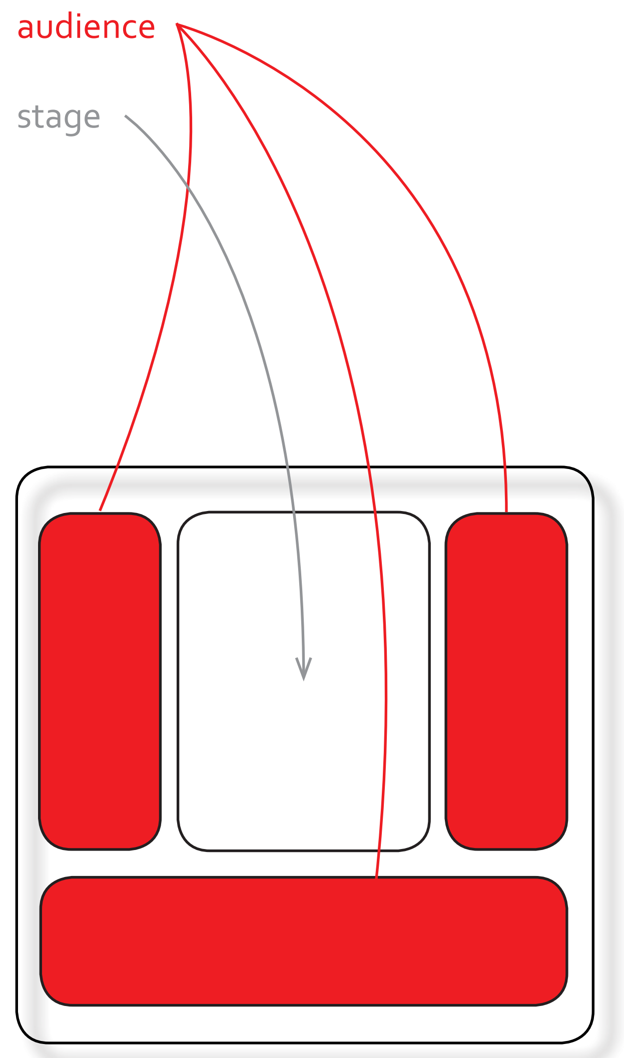
total
17,280 sq. ft.



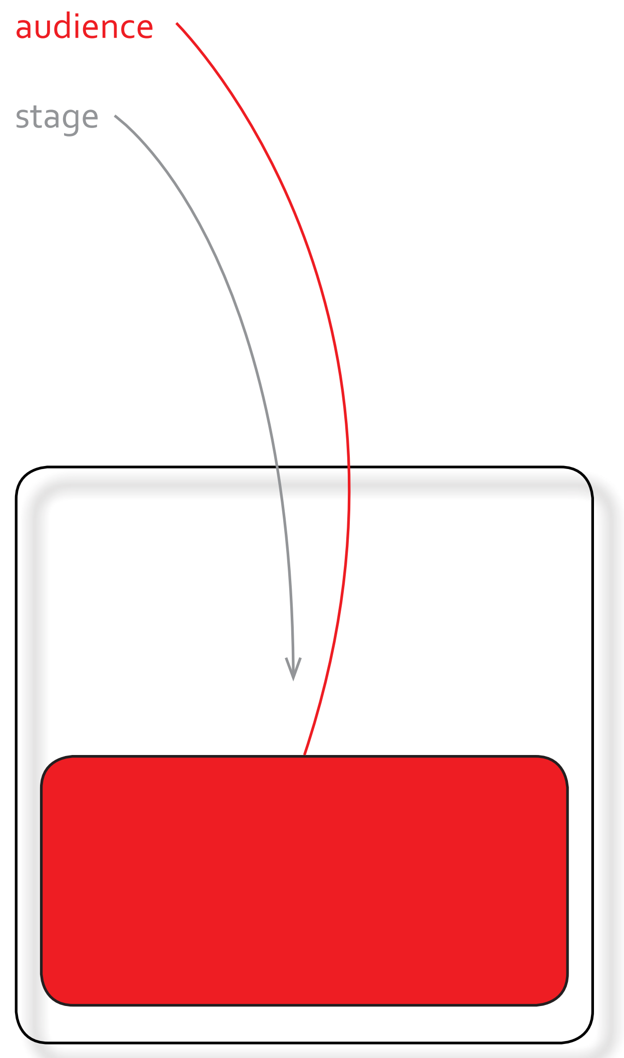

not required
desired
required
directors office
teachers offices
employee bathroom
mechanical
crows net
sound.projection
changing rooms
stage
set.storage
rehearsal.practice
conference rooms
maintenance.janitor
locker room
public bathroom
lobby.lounge
auditorium
receptionist
courtyard
mail.storage
director's office
teachers' offices
employee bathroom
mechanical
crows net
sound & projection
changing rooms
stage
set & storage
rehearsal & practice
conference rooms
maintenance
locker room
public bathroom
lobby & lounge
auditorium
reception
courtyard
mail & storage


sound & projection
director's office
teachers' offices
conference rooms
employee bath.
mechanical
changing rooms
locker rooms
set & storage
rehearsal practice
maintenance
storage & mail
break & lunchroom
reception
lobby
courtyard
public bath.
auditorium
stage
crows nest
formal connection
informal connection
casual connection
public
private
auditorium

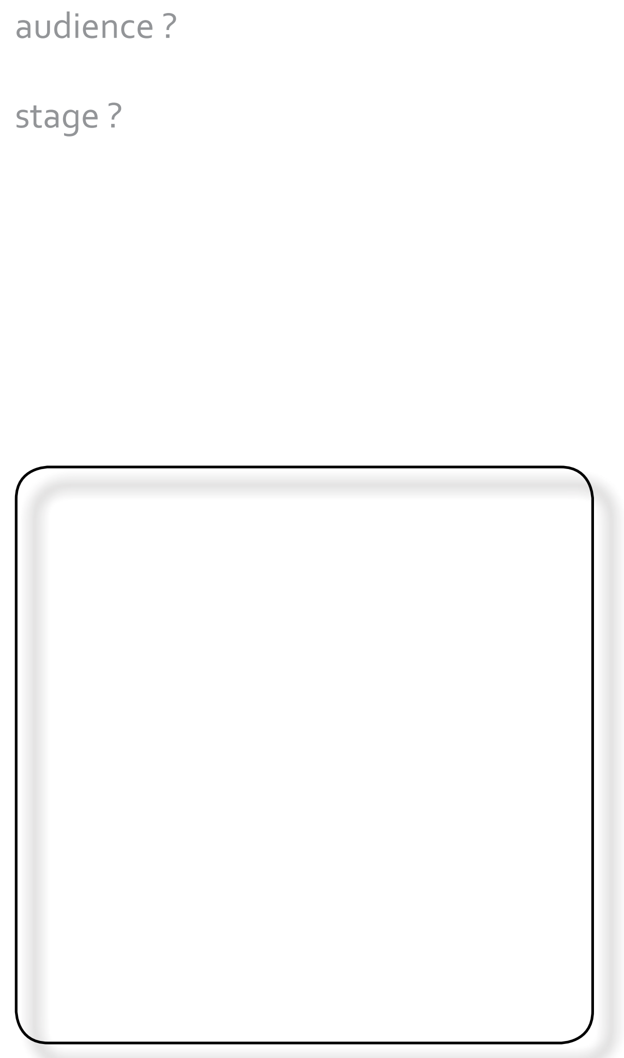

UNFOLD/TRANSFORM
LOCKER ROOMS
LOBBY LOUNGE
HEART



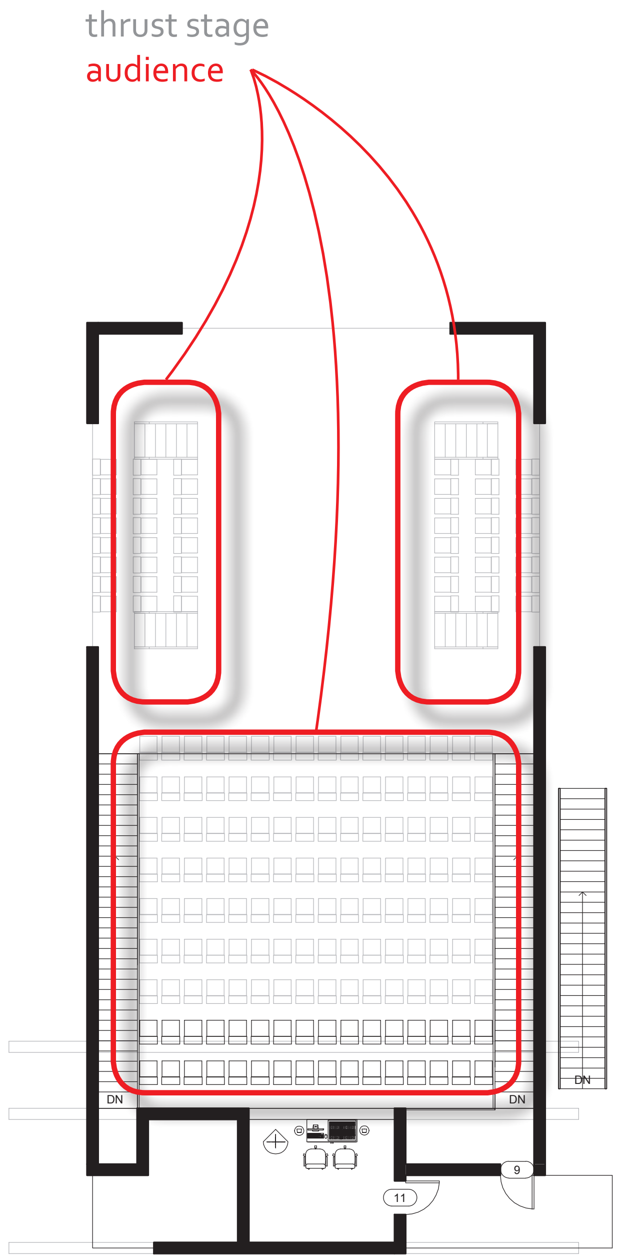
thrust stage - the stage is placed in the center of the theater giving each member of the audience a unique viewpoint of the performance.

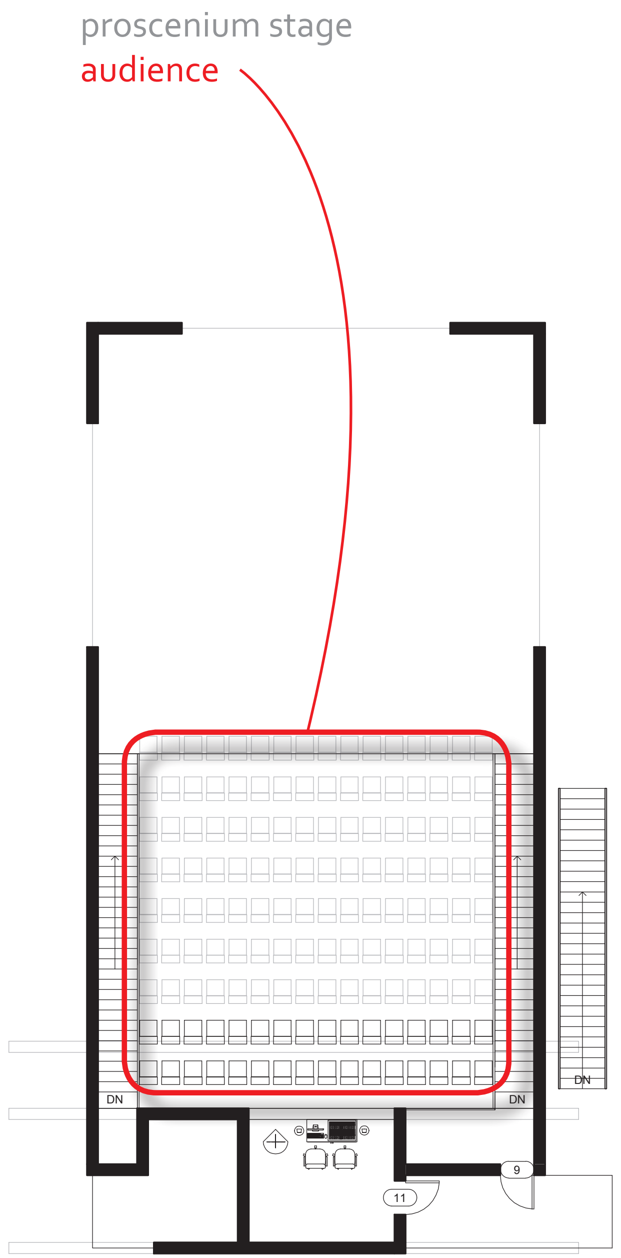


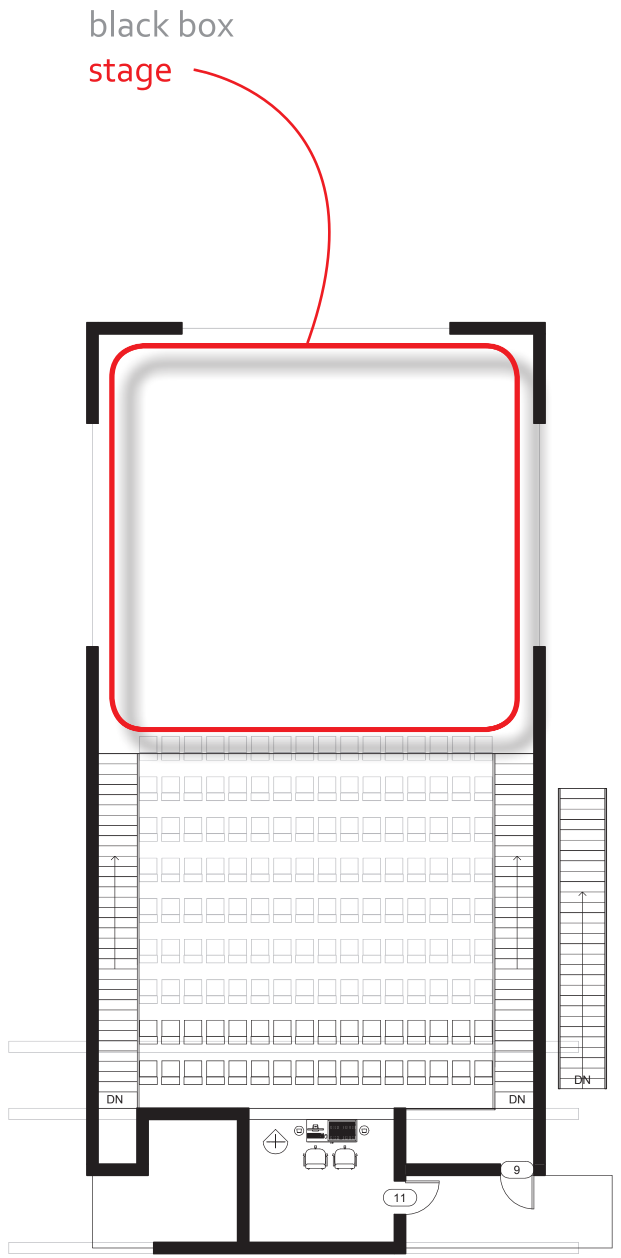
proscenium stage - all members of the audience share the same 'direct' viewpoint to the stage. the proscenium is the most traditional of the three types.

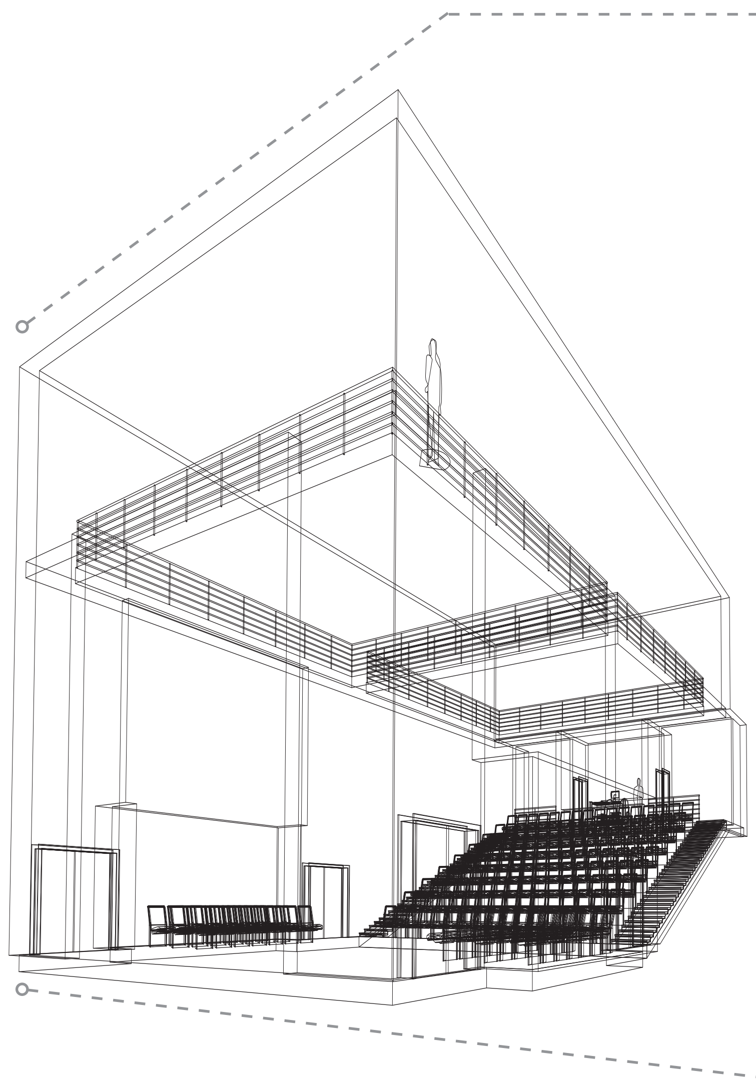


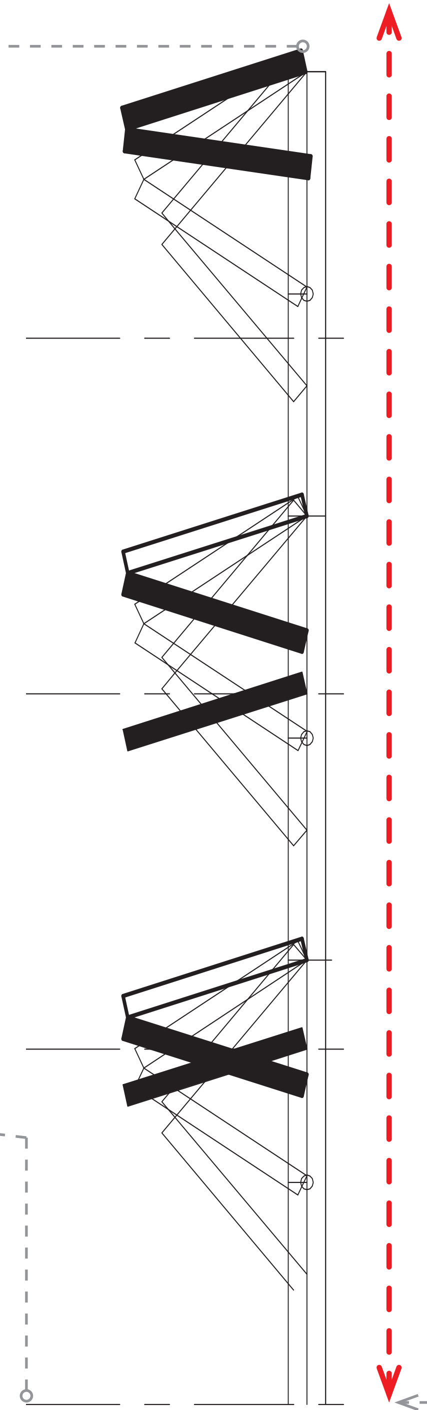
black box - the most versatile type. relies heavily on moveable seating and lights. emphasis is placed on the talent of the actors and the imagination of the audience

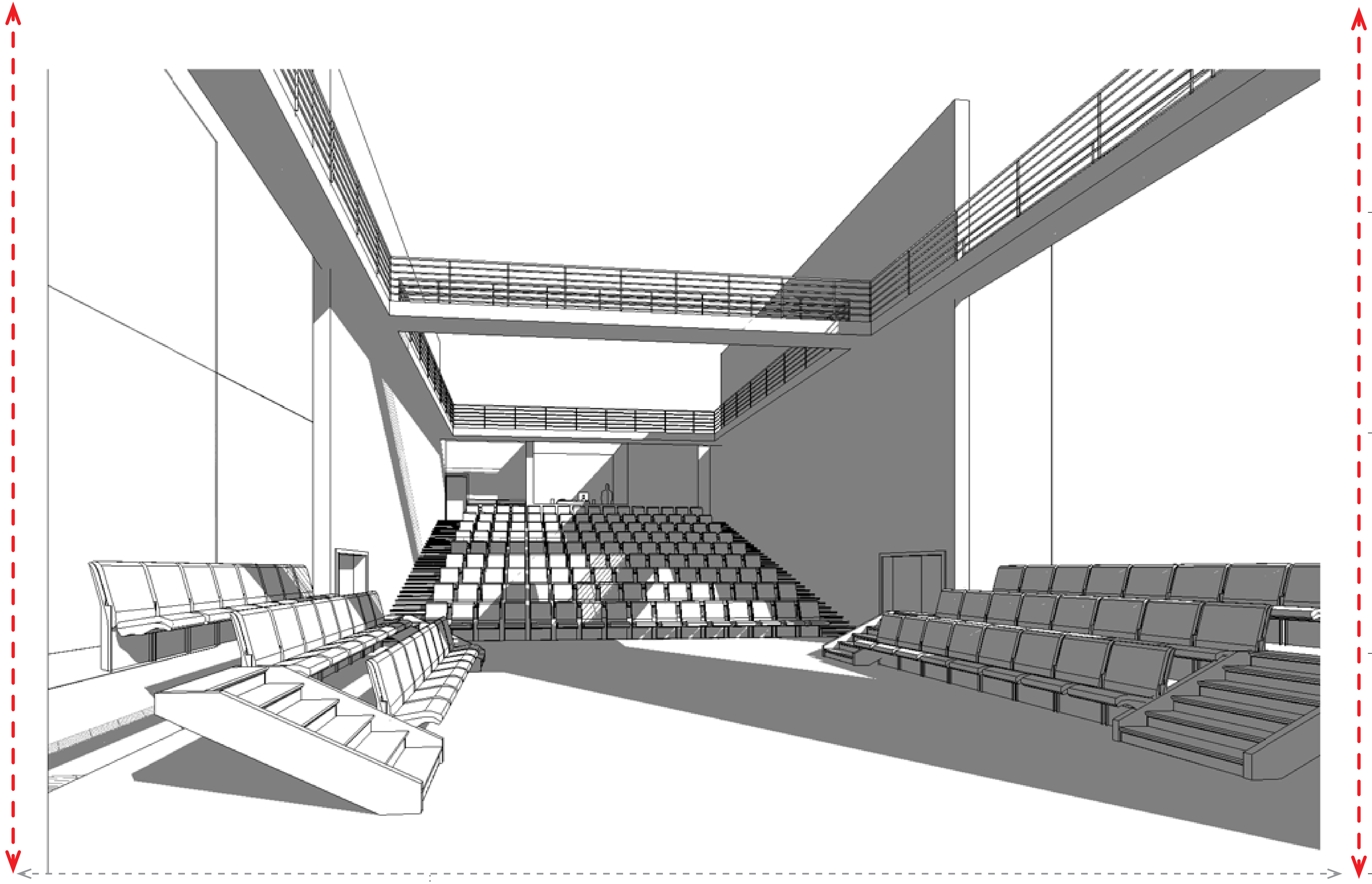


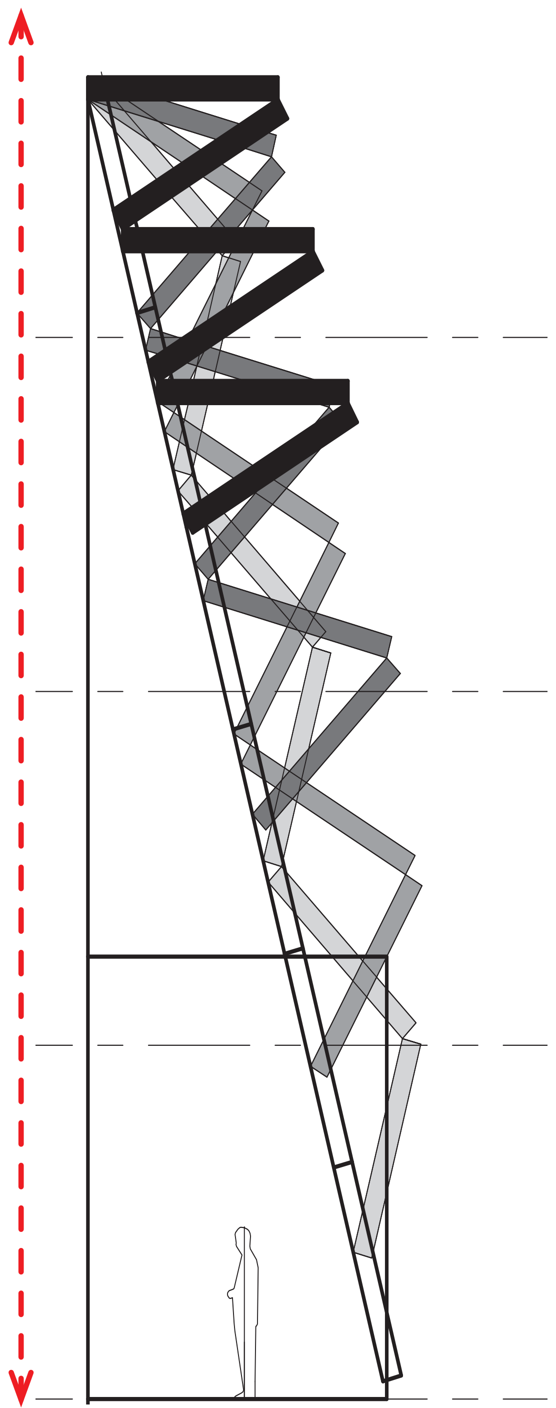






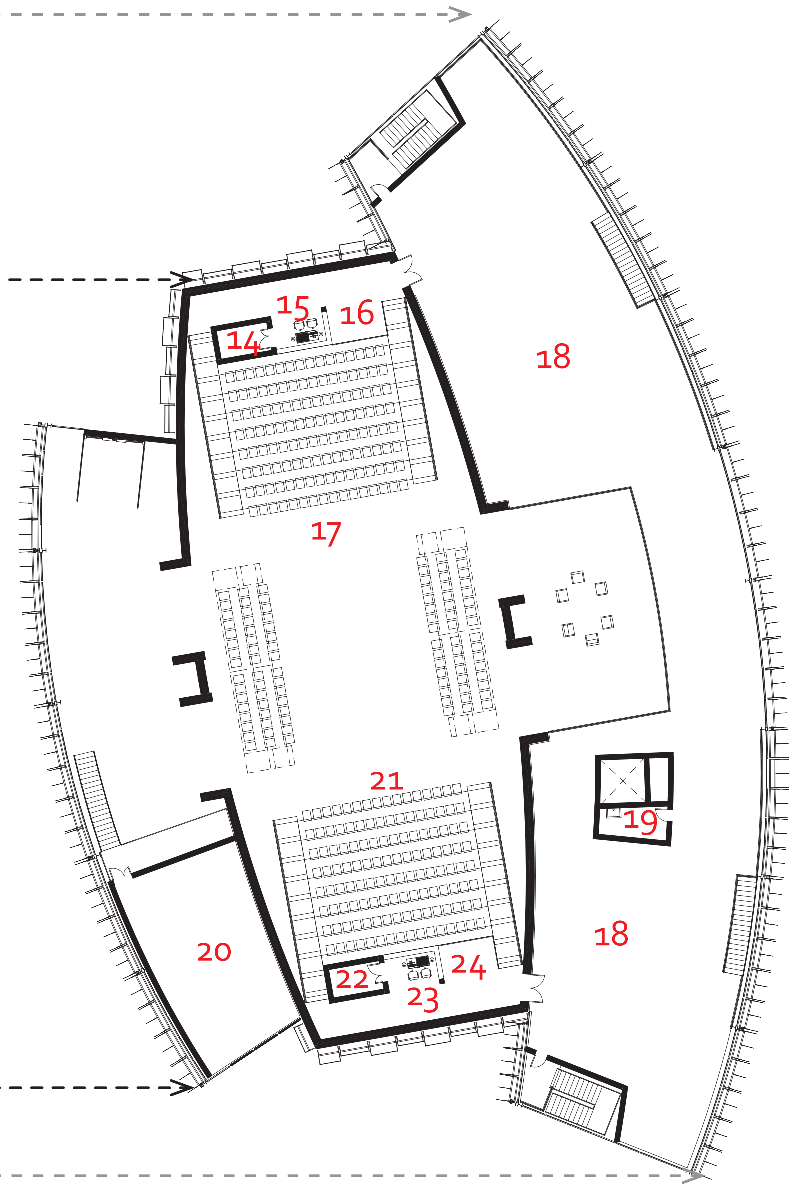






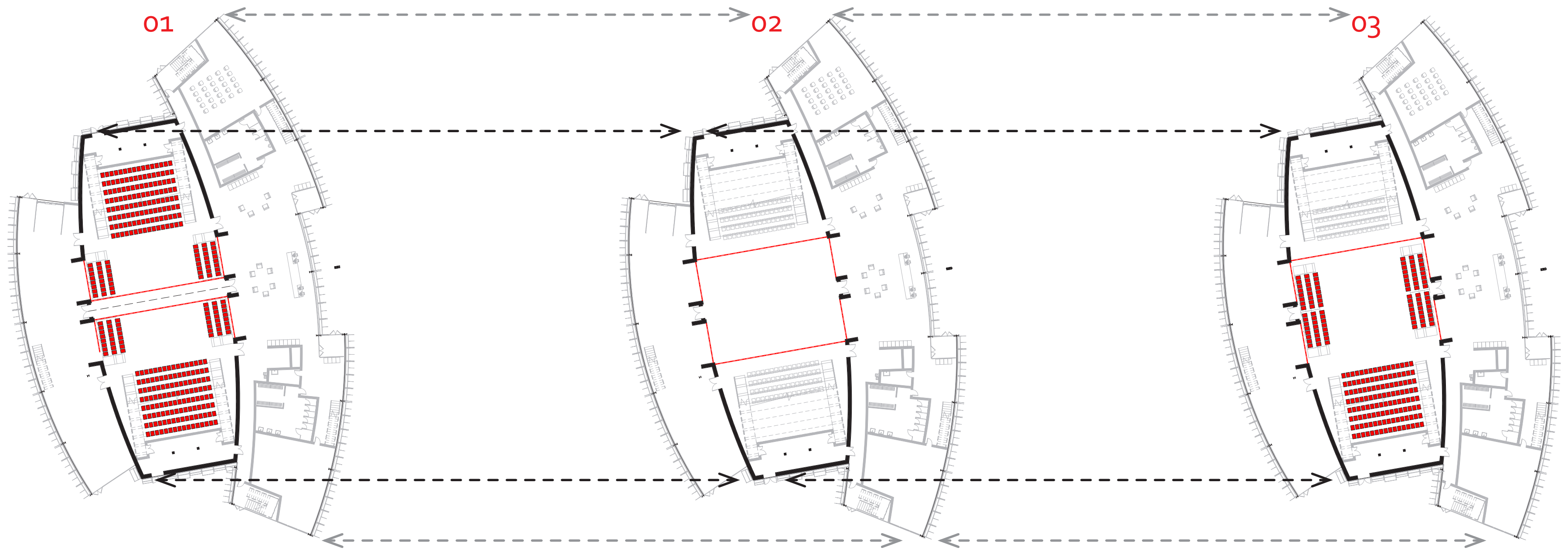
folding partition walls - performing acoustic separation, distribution of daylight, and privacy. the partitions fold upward, into the ceiling, requiring no floorspace. the operation is quiet, and would require no skilled labor. application of kinetic elements into a static framework enables response to a dynamic and diverse program.

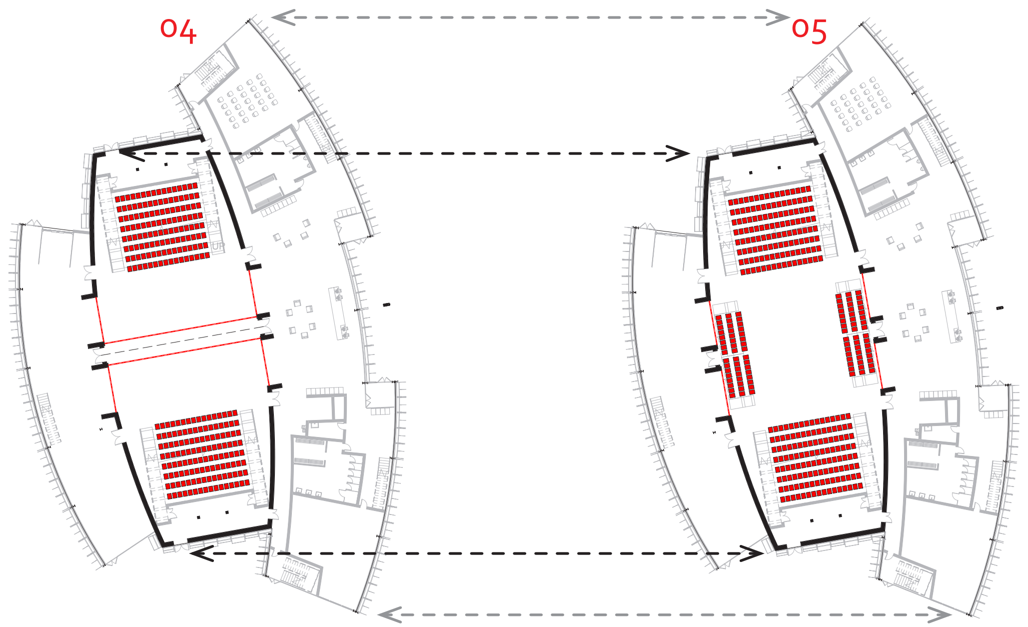
01 classroom
02 locker room
03 mens bath
04 auditorium
05 lounge
06 backstage
07 stage
08 janitors closet
09 storage
10 auditorium
11 womens bath
12 locker room
13 mechanical



level two (n.t.s)

14 video
15 sound booth
16 handicap seating
17 auditorium
18 studio classroom
19 janitors closet
20 boiler room
21 auditorium
22 video
23 sound booth
24 handicap seating





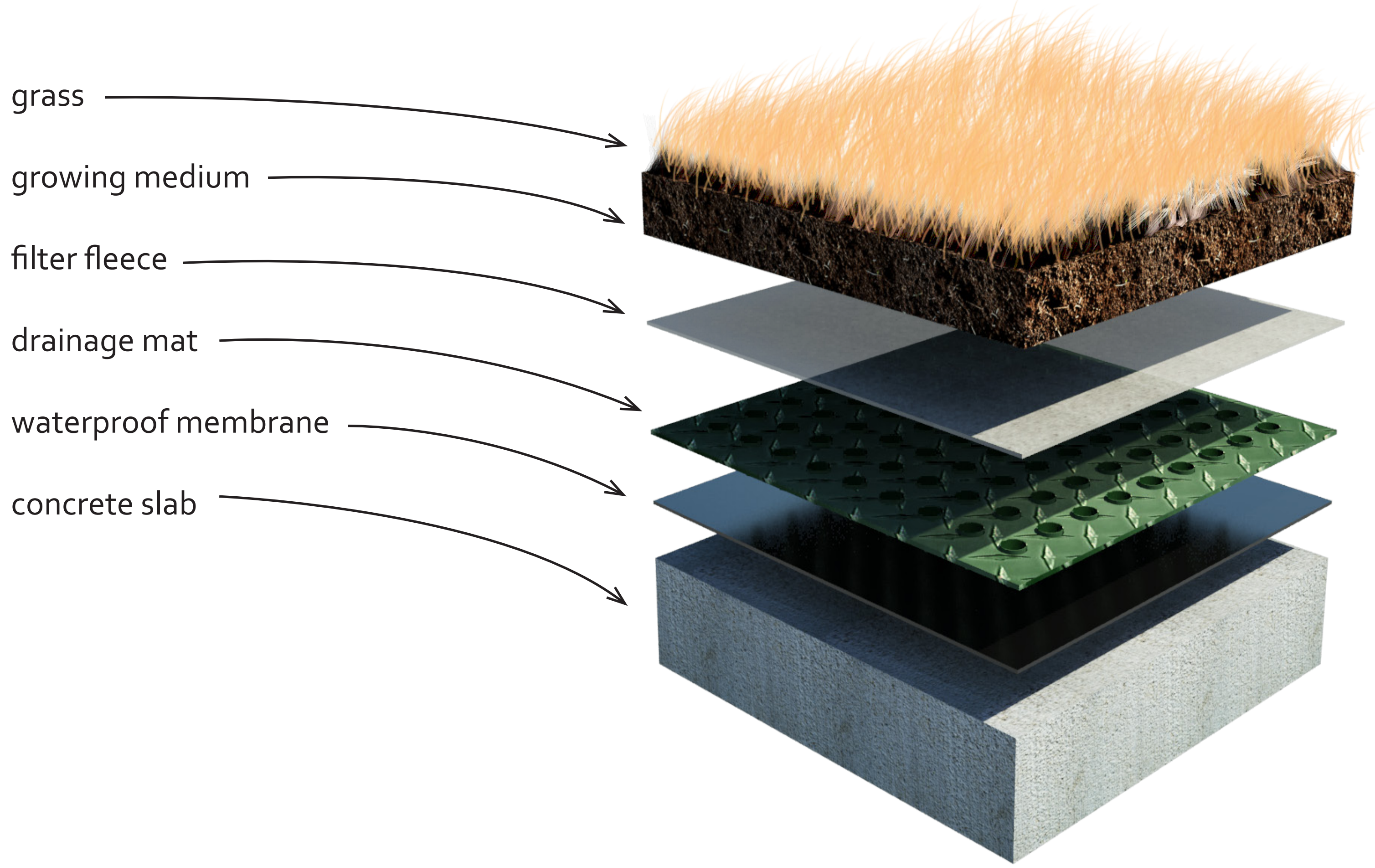
01 2 x thrust stage

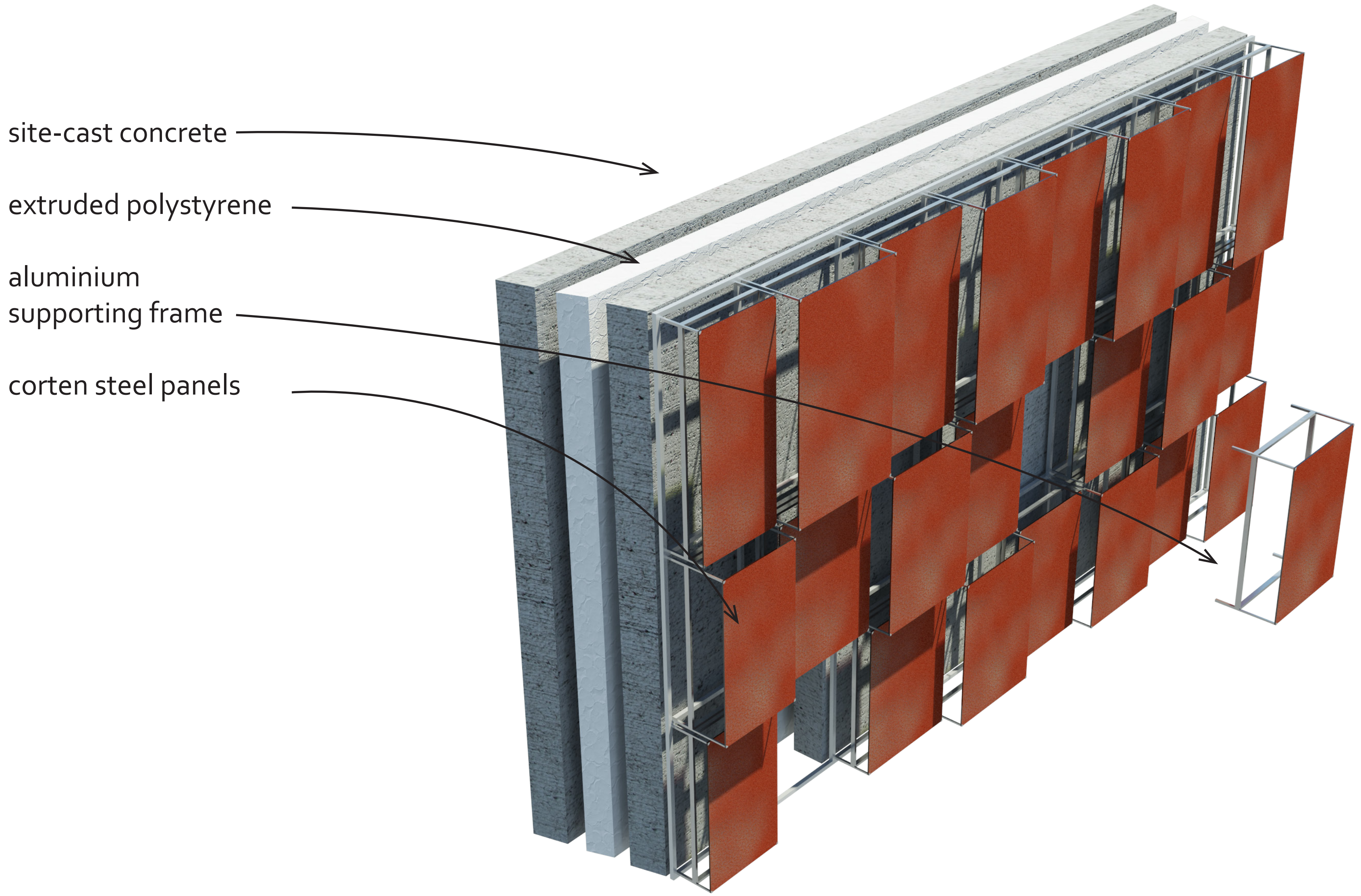
02 box stage

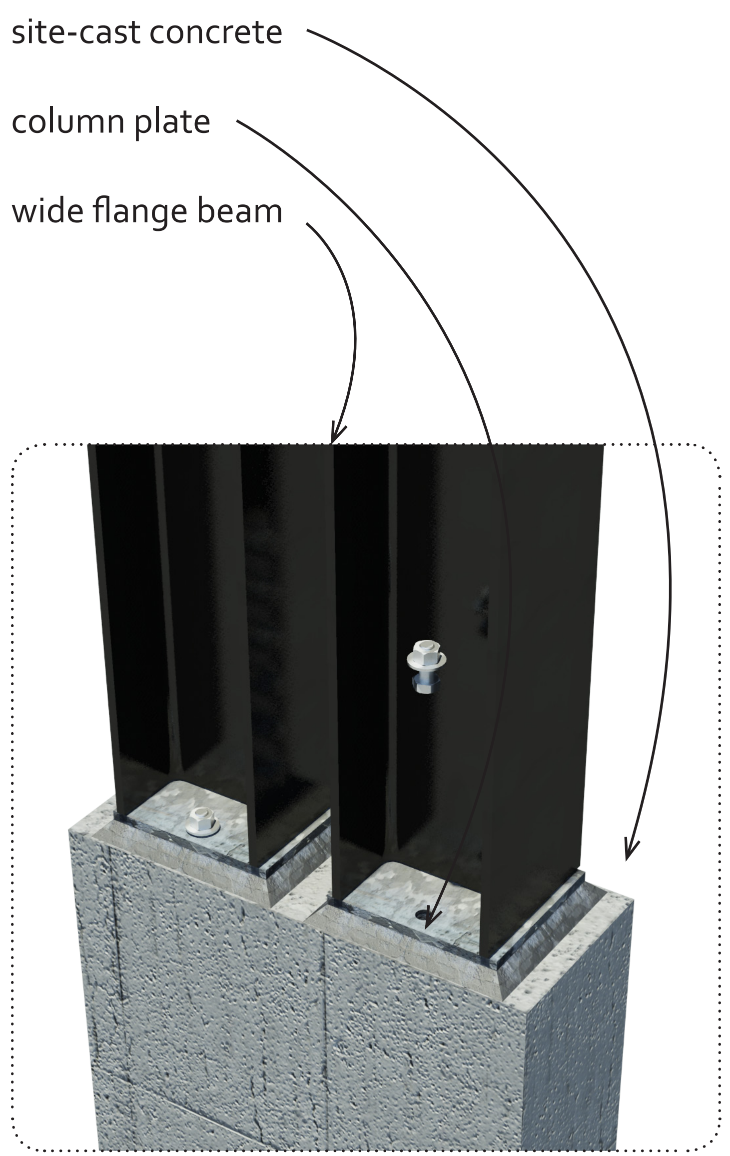
03 thrust stage

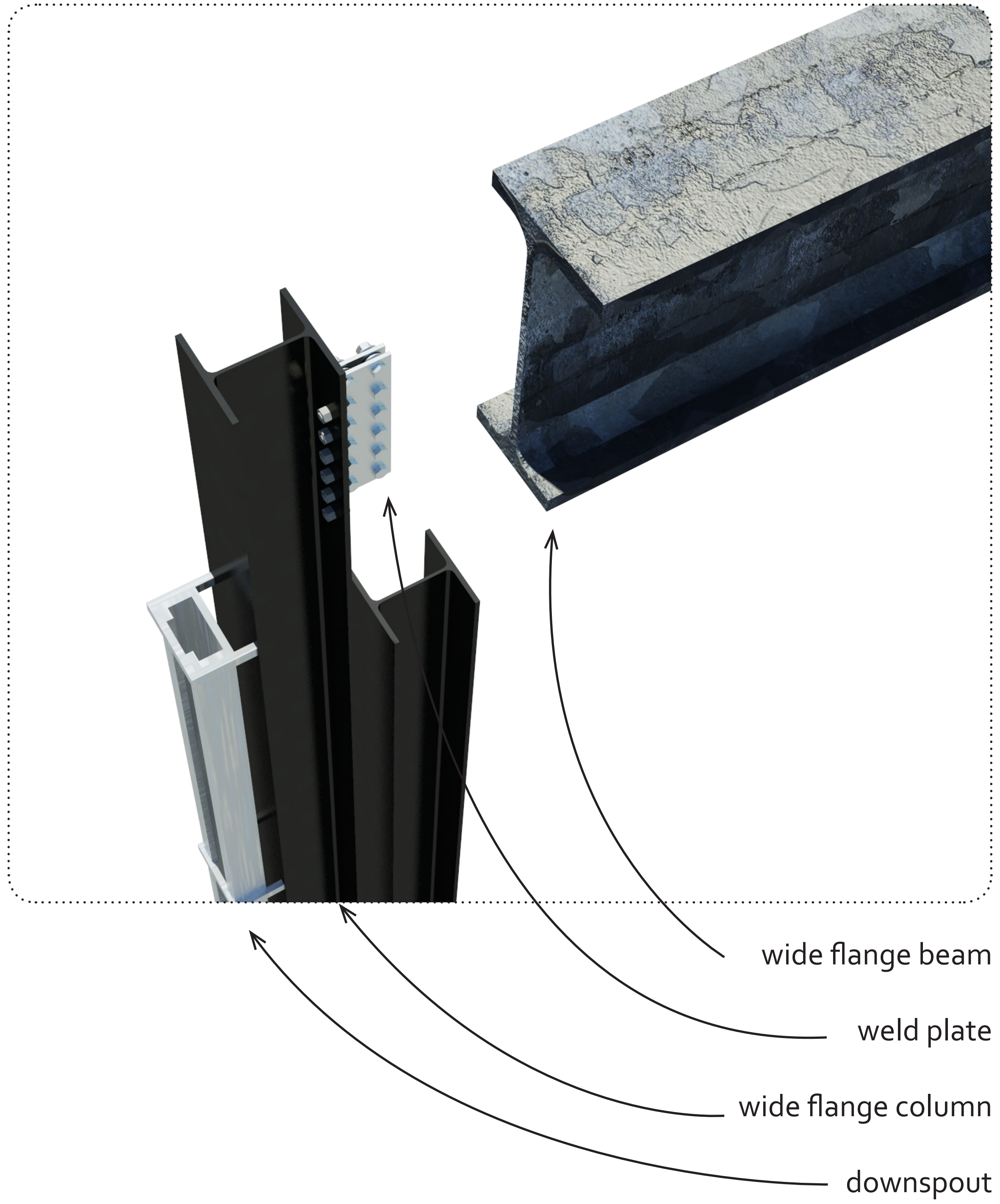
04 2x proscenium stage

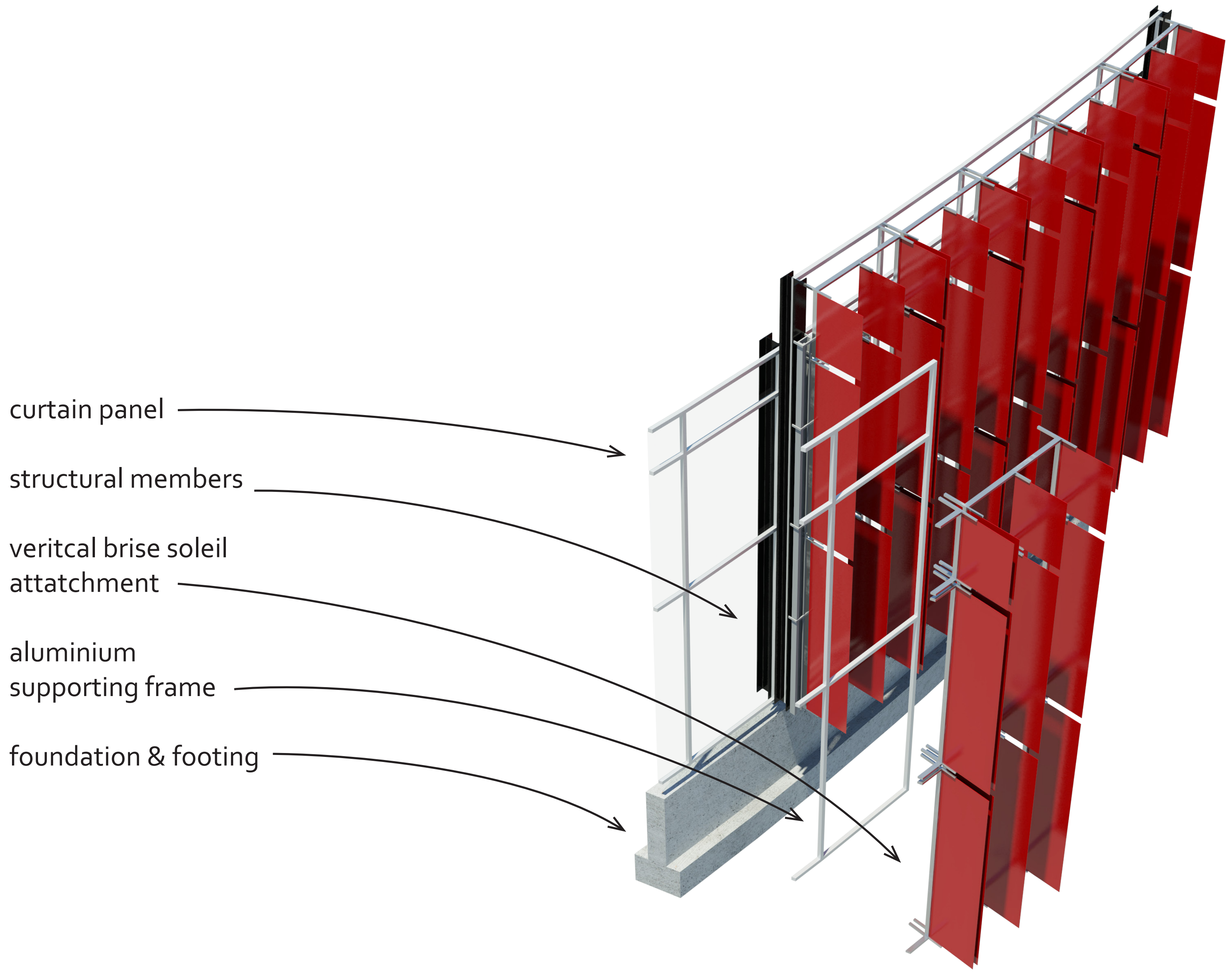
05 round stage

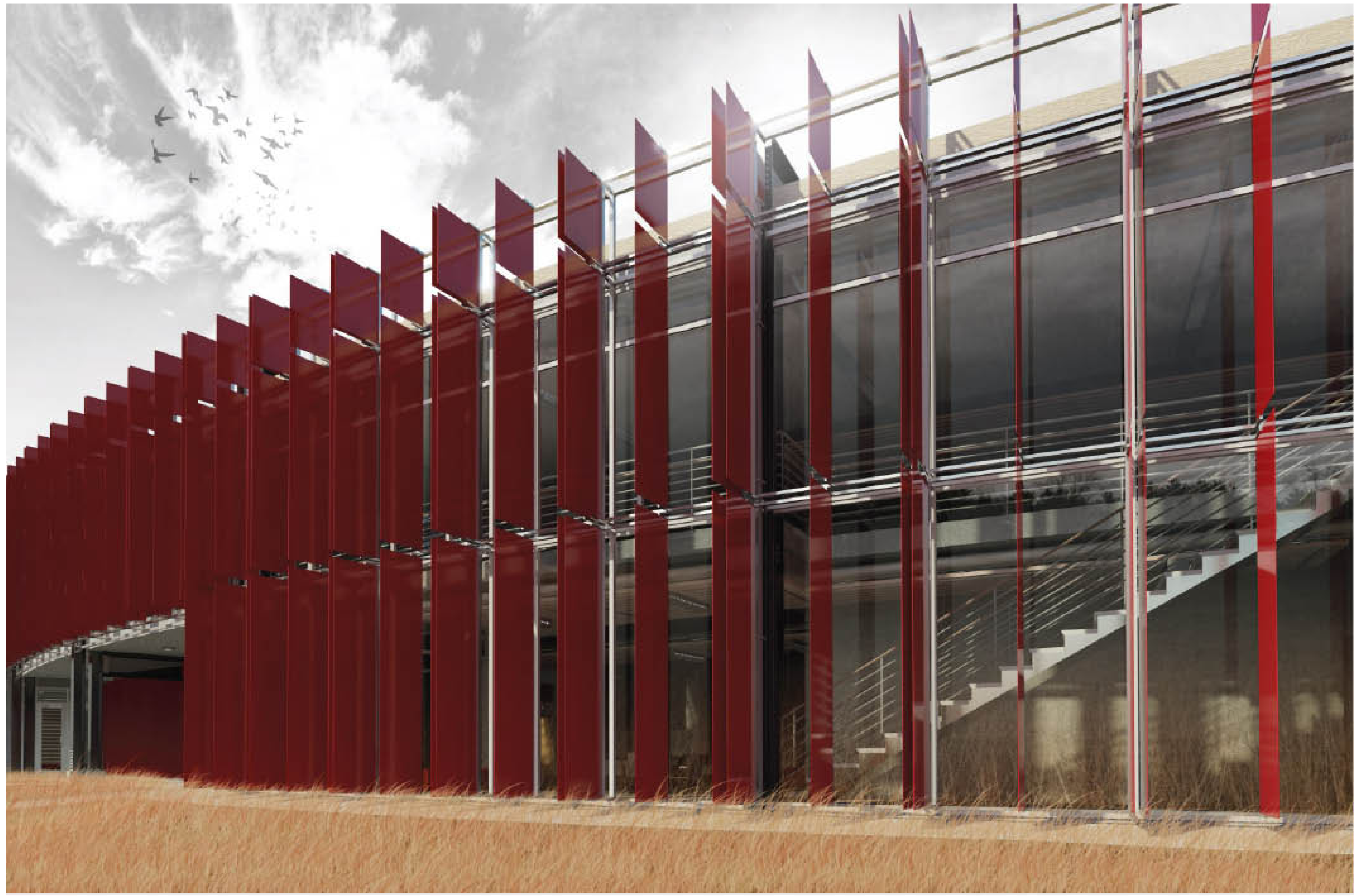



site-cast concrete
extruded polystyrene
aluminium
supporting frame
corten steel panels


site-cast concrete
column plate
wide flange beam


wide flange beam
weld plate
wide flange column
downspout


curtain panel
structural members
veritcal brise soleil
attatchment
aluminium
supporting frame
foundation & footing




WICKED
MOULIN ROUGE
LITTLE SHOP OF


1
2
3
4
5
arch 722 | design thesis
spring semester 2012
matthew collianni | bakr m aly ahmed
revit, 3ds max, illustrator, photoshop


responsive frameworks
polyfunctional space for dynamic stimulus
this thesis investigates the question 'how does a building repond to dynamic stimulus over time? a performing arts center at the non-profit minnetonka center for arts is the vehicle for research. as the building program and users change throughout the day, this solution responds through a flexible framework enabling the client to modify the central space to suit their needs. the goal of this research is to produce a model that addresses efficiency of space and embodied energy in addition to satisfying current trends in theater design.

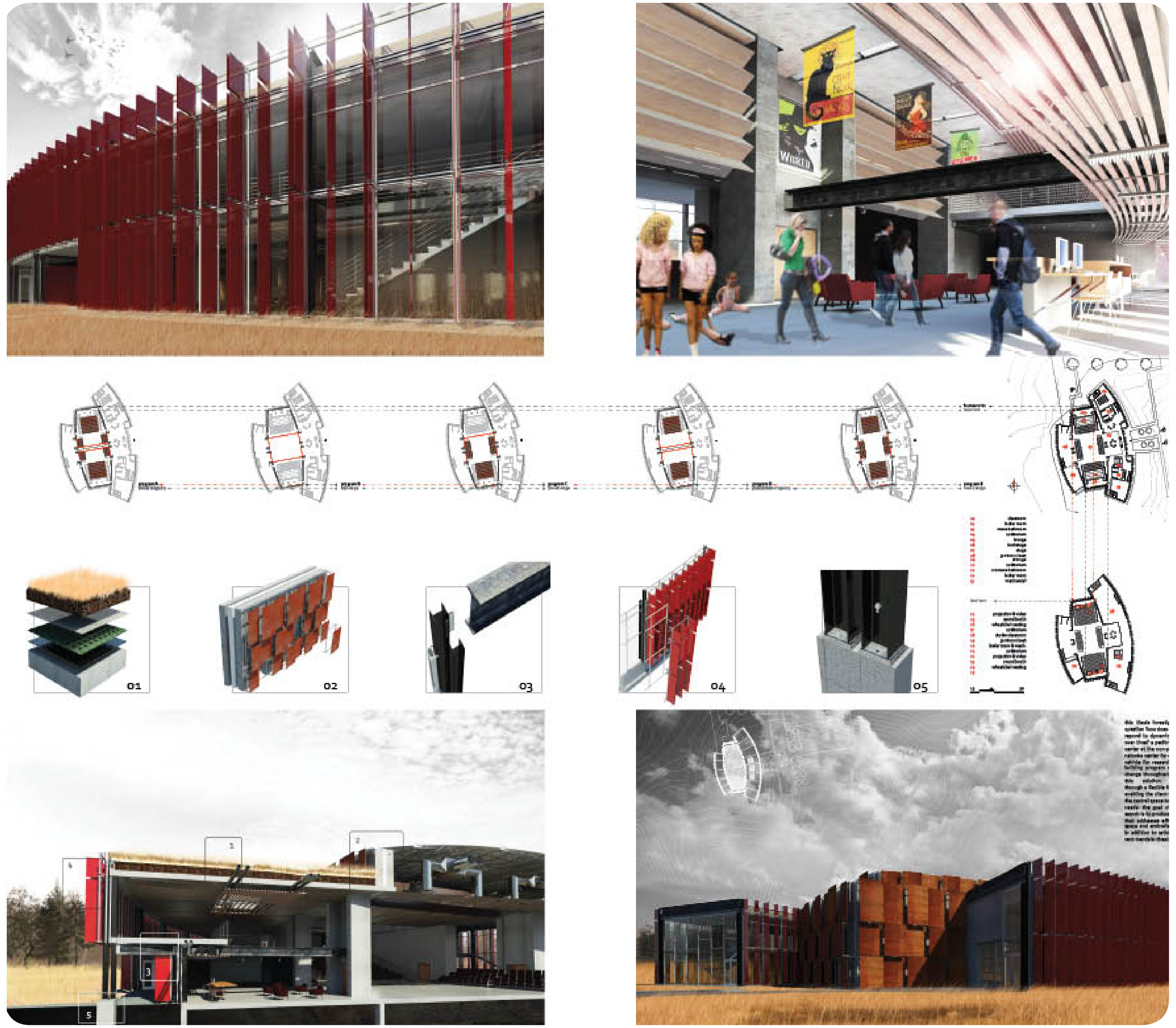


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fig 1.1 (http://www.architizer.com/en_us/projects/pictures/municipal-theater-of-zafra/31192/267459/)

fig 1.2 (http://www.architizer.com/en_us/projects/pictures/wild-beast-pavilion/27404/233723/)

fig 1.3 (http://www.dezeen.com/2010/08/26/taastrup-theatre-by-cobe/)

fig 2.1 (http://www.architizer.com/en_us/projects/pictures/municipal-theater-of-zafra/31192/267510/)

fig 2.2 (http://www.architizer.com/en_us/projects/pictures/municipal-theater-of-zafra/31192/267518/)

fig 2.3 (http://www.archdaily.com/120538/municipal-theater-of-zafra-enrique-krahe/untitled-38/)

fig. 3.1 (http://www.architizer.com/en_us/projects/pictures/wild-beast-pavilion/27404/233723/)

fig 3.2 (http://www.archdaily.com/154187/the-wild-beast-hodgetts-fung-design-and-architecture/dc1design-staff-hf-projects0550-calarts0550_03-design-data/)

fig 3.3 (http://www.architizer.com/en_us/projects/pictures/wild-beast-pavilion/27404/233741/)

fig 4.1 (http://www.archdaily.com/86180/taastrup-theater-cobe/section-02-206/)

fig 4.2 (http://www.dezeen.com/2010/08/26/taastrup-theatre-by-cobe/)

fig 4.3 (http://www.dezeen.com/2010/08/26/taastrup-theatre-by-cobe/)

fig 4.4 (http://www.archdaily.com/86180/taastrup-theater-cobe/section-02-206/)

"an idea is salvation by imagination"
frank lloyd wright

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