NATIVE REVERBERATION: ARTISTIC ACOUSTICS FOR THE OUTDOOR STAGE ON THE CASTLE CREEK CAMPUS

by

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A REPORT

submitted in partial fulfillment of the requirements for the degree

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Abstract

This project addresses landscape acoustics for a complex site and complex program. The site is a campus owned by two separate yet equally important entities, the Aspen Music Festival and School and the Aspen Country Day School. Each owner has very different program requirements for the Campus. Because of a mountainous setting the Campus is surrounded by natural hazards affecting the development potential of the site. Most importantly, the program requires performance and practice spaces for the music students. These spaces should be acoustically sound. However, acoustics in the outdoors is rarely thought of in the design profession. More often, sound is considered strictly in the sense of noise control.

Carefully placing and designing the outdoor spaces for the students will enhance the acoustic quality, environmental sensitivity and unity of the campus as a significant and unique place. To enhance the acoustical experience of the Castle Creek Campus this research addresses what characteristics affect the movement of sound. This research identifies which outdoor environments propagate or hinder sound movement.

A comparative sound study first identifies, locates and records characteristics of the campus. Some of these characteristics include the height of tree canopy, amount of enclosure, and surface type, for example. The audio recordings of the characteristics are then analyzed quantitatively and qualitatively, and ranked accordingly. This method allows for replicable results in other geographical areas.

The ranking system results show that the appropriate location for the primary performance space is near calm water with little obstruction on three sides. The location for the practice spaces is generally, most appropriate in heavily wooded areas with dense canopy coverage. The results of the research guide the location and design of the required outdoor performance and practice spaces for the Castle Creek Campus serves as an example for incorporating acoustics into design.

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native reverberation

artistic acoustics for the outdoor stage on the castle creek campus

a master's project + report by robin banks

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acknowledgements

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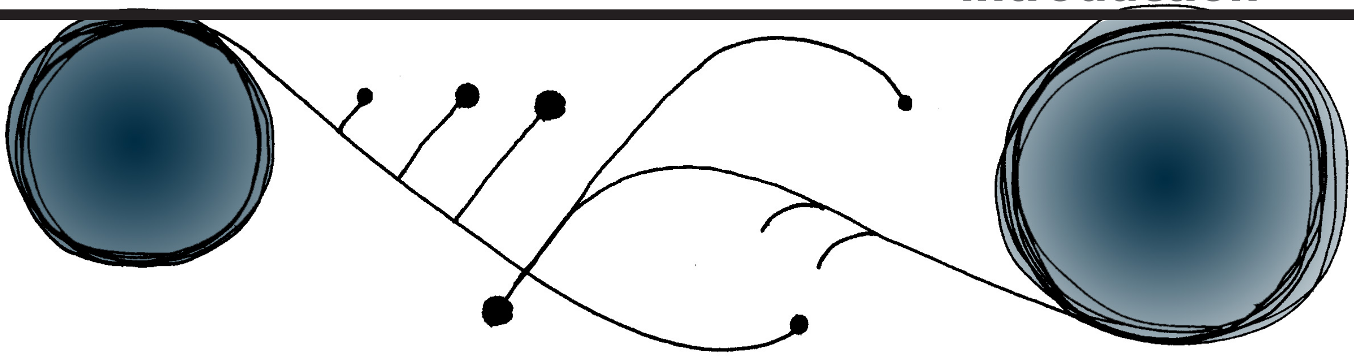
introduction



dilemma

How can the site design create inspiring and acoustically sound spaces for the students of Aspen Country Day School and Aspen Music Festival and School while addressing the hazardous constraints on the site in a manner that promotes sustainable site design?

Within this dilemma there are four fundamental subjects to be explored through the research and design of the campus: inspiration, quality outdoor acoustics, solving hazardous site constraints, and promoting sustainable practices. The need to innovate and inspire are the underlying requirements for any design decision. The campus is set in a naturally spectacular setting which the Aspen Country Day School and Aspen Music Festival and School feel is a primary source of inspiration for their students. Because inspiration already exists on the site, it is a part of the overall dilemma due to the concern that the inspiration quality may be lost through redevelopment.

Quality outdoor acoustics is not something that has been studied extensively. Acoustics is not an area of study that many landscape architects consider when beginning a project. On the Castle Creek Campus in particular acoustics plays a large role in every aspect of the building design, therefore, why shouldn't acoustics also be just as important in the design of the site?

Natural elements on the site greatly impact its redevelopment. The site is located in a very narrow valley between two mountain peaks: to the east, Aspen Mountain and the west, Highlands Mountain. These steep grades create moderate to severe avalanche areas, moderate to severe snow slide areas, rockfall areas and an elk migration corridor. In addition, Keno Gulch empties onto the property, releasing a high amount of runoff onto the site.

Castle Creek runs through the campus splitting it in two. The creek restricts site development further due to the floodplain. This also creates very highly valuable riparian area which is required by city and county regulations to be mitigated if disturbed. Which leads to another facet of the dilemma, Pitkin County, CO is one of the most heavily regulated counties in the country in terms of building permit approval. The county is strict on riparian mitigation, scenic byways, as well as building on or adjacent to 30% or more slopes.

The final concern within the overall dilemma is related to sustainable site design. Sustainability is something that should and will be incorporated into every future project. However, the hazardous site conditions make applying some LEED standards and Sustainable Site Initiative Guidelines difficult.

thesis

Rethinking the boundaries of the current site layout will orient the buildings and design in a more organized and meaningful manner. Exploring the application of acoustical measurements and standards explained by Frederick White, Leo Beranek and Ian Appleton will enhance the usability of outdoor spaces. The implementation of more informal outdoor practice spaces will lessen the need for formal, built practice rooms which expand the development footprint on an already tight site. Incorporating LEED standards will provide opportunities to create more artistic and inspiring places for students to practice an instrument or a school child to expand their imagination. Addressing the site constraints through LEED will result in a safer and longer lasting campus that requires less maintenance.

The new Castle Creek Campus will support the economic, artistic, environmental, and community success of the City of Aspen by creating a unique setting for the one of the towns most successful and enriching events/programs. Enhancing the acoustics of the campus performance spaces will bring even more prestigious musical faculty and students to the area, who will contribute to the economic growth of the Aspen area. Providing such outdoor spaces will also provide the community with more opportunities for interaction with the schools and their students to everyone's benefit.

> ***Carefully placing and designing outdoor performance and practice spaces for the students will enhance the acoustical quality, environmental sensitivity by lessening building footprints, and unity of the campus as a significant and unique place.***

key issues relevant to landscape architecture

The redevelopment of Castle Creek Campus will address multiple issues in landscape architecture such as site soundscapes, Leadership in Energy and Environmental Design (LEED), and Sustainable Site Initiatives.

Sound is something that is always a concern in the profession today. However, typically sound is thought of in a negative way as "noise" which should be avoided and eliminated wherever possible. Although this is an important part of designing spaces, sound should be considered as an asset in design. The understanding of the positive effects of sound in relation to the landscape has been studied very little and is often overlooked for the more visual aspects of design. This report and project are meant to enhance the particular site soundscapes of the Castle Creek Campus, and expand knowledge of outdoor acoustics within the landscape architecture profession.

In addition, popular culture today is becoming more focused on being "green." Many Americans are looking for ways to make their home more environmentally friendly to reduce their carbon footprint. Architects are designing their building to meet strict standards in sustainability certification for various organizations. Federal, state and local governments are putting these environmentally sensitive building standards and alternative fuel options into law.

LEED is a forefront issue in landscape architecture today. It is being applied to new building construction on a very regular basis, yet the site application of the basic principles is still in the preliminary stages. One LEED program in the preliminary stages is LEED Neighborhood Development (ND), which addresses many of the New Urbanism and planning based standards, but there is nothing yet related to the site scale in LEED. The Sustainable Site Initiative (SSI) through American Society of Landscape Architects (ASLA) is working to change this. The guidelines, now in final draft form, attempt to give structure and motivation to sustainably responsible site development, much like LEED does for buildings.

Finally, uses for this campus are particularly creative. Today, much of Landscape Architecture speaks of making place as art, but few actually apply this theory for practical reasons. The Castle Creek Campus has great opportunity to present itself as an artistic and inspirational place.

background

location of the site

Castle Creek Campus
Aspen, Colorado - 2 miles
Southwest of downtown Aspen
Size of site - 22.78 Acres

Fig. 1: location map of the Castle Creek Campus in relation to downtown Aspen, CO
Adapted from Design Workshop Inc., 2008

history

The site's recorded history began in 1879 when George E. Newman opened a mine on the spot, then converted it into a Tudor estate on the earnings. He enlarged two natural springs into ponds and modeled the main building after an English club on Piccadilly Circus in London in response to Aspen's growing popularity as a resort destination. In 1949 Elizabeth and Walter Paepcke of Chicago launched a two-week celebration on the site, the Goethe Bicentennial Convocation. Here began the intersection of ideas, art, and natural beauty which is still a pivotal part of both the Music Festival and Country Day School. (Aspen Country Day School 2008)

This history enriches the character of the campus by giving it a distinct and genuine quality. This character is in danger of being lost. The rustic qualities of traditional mountain homes existing on the campus are being transformed through the process of updating and modernization of the buildings and grounds.

- **1879** – George E. Newman opened silver mine
- **1949** – Elizabeth + Walter Paepcke launched two week celebration of the Goethe Bicentennial Convocation and Music Festival in Aspen, CO.
- **1951** - The Aspen Music School is added to the Festival organization
- **1950's** – numerous faculty from Julliard join the Aspen family
- **1965** – main performance tent (located in downtown Aspen) is designed raising seating capacity from 900 to 1,750 but is not realized until later.
- **1969** – Aspen Music Festival and School gives a winter lease to the Aspen Country Day School
- **1993** – The 500 seat Harris Hall opens, providing the Music Festival and School with a state-of-the-are, acoustically superior facility for year-round concerts.
- **1999** – Benedict Music Tent opens seating 2,050 (located in downtown Aspen)
- **2001** – a joint venture between the Aspen Music Festival and School + Aspen Country Day School begin to rebuild the Castle Creek Campus.

(Source: *Aspen Music Festival and School 2008*)

users/clients

The Castle Creek Campus plays host to more than 1,000 students each year between its two owners, the Aspen Country Day School and the Aspen Music Festival and School. It has been serving these entities for nearly 60 years with great success. The Country Day School is an extremely prestigious elementary school in the Aspen area for students age two and a half through eighth grade (13 years old). The school takes pride in its mission:

> *"...fostering a culture of learning by which each child reaches his or her potential. In an inspiring setting of natural beauty, we offer a rigorous curriculum and individualized education while creating a love of learning, personal growth and responsible citizenship."*

There is an emphasis on balancing academics, the arts, and outdoor education. The campus itself is a very large part the curriculum and activities associated with both owners.

The Aspen Music Festival and School moves on to the campus each summer. This festival is known for bringing the brightest young musicians together with the classical music world's foremost instructors. The philosophy of the music school focuses on rigorous education, artistic expression and natural beauty. It welcomes more than 700 students and 200 artist-faculty each year. These students and most of the faculty are summer-only occupants.

goals + objectives

To guide the design decisions for the campus specific goals and objectives have been established. The goals directly relate to the statements made in the thesis (p. 3).

Goal 1 - Bring small performance venues outdoors without losing acoustic quality.

- Objective 1: define "good" acoustics in relation to the Castle Creek Campus.
- Objective 2: Create a number of intimate spaces for students to practice determined by the program required by the clients.
- Objective 3: Determine which vegetation types best propagate sound.

- Objective 4: Determine which types of performance space are best suited to the outdoors.
- Objective 5: Create a multifunctional gathering space for both clients.

Goal 2 - Increase student enrollment

- Objective 1: update aging facilities or completely demolish and rebuild where necessary.
- Objective 2: make the campus unique in comparison to other musical institutions through innovative site design and outdoor acoustic quality.

Goal 3 - Incorporate Sustainable Site Initiative (SSI) guidelines into the placement and design of spaces and the campus in general

- Objective 1: preserve the natural character of the site both architecturally and site-wise.
- Objective 2: enhance and/or preserve the water quality of Castle Creek.
- Objective 3: alleviate development pressure on the site by strategically reducing program requirements (in terms of building square footage).
- Objective 4: use native vegetation, requiring less irrigation.
- Objective 5: protect the extent and quality of riparian areas and wetlands.
- Objective 6: identify problem areas containing poor hydrologic cycles and rectify in master plan.

Goal 4 - Express the importance of sound in the design of **all** exterior spaces, not simply "noise" control.

- Objective 1: express the physical implications sound has on the human experience.
- Objective 2: describe the physiological effects of sound due to the physical changes associated with sound.

project process

The development and application of previously unknown subject matter (to the author) such as acoustics calls for pre-design research (*see Fig 2*). The process starts with in-depth literature research of acoustics in order to first gain understanding, then the identification of issues and opportunities on the site. The project process focuses on establishing a method by which to solve the dilemma and test the thesis in relation to time (*see Fig 3*).

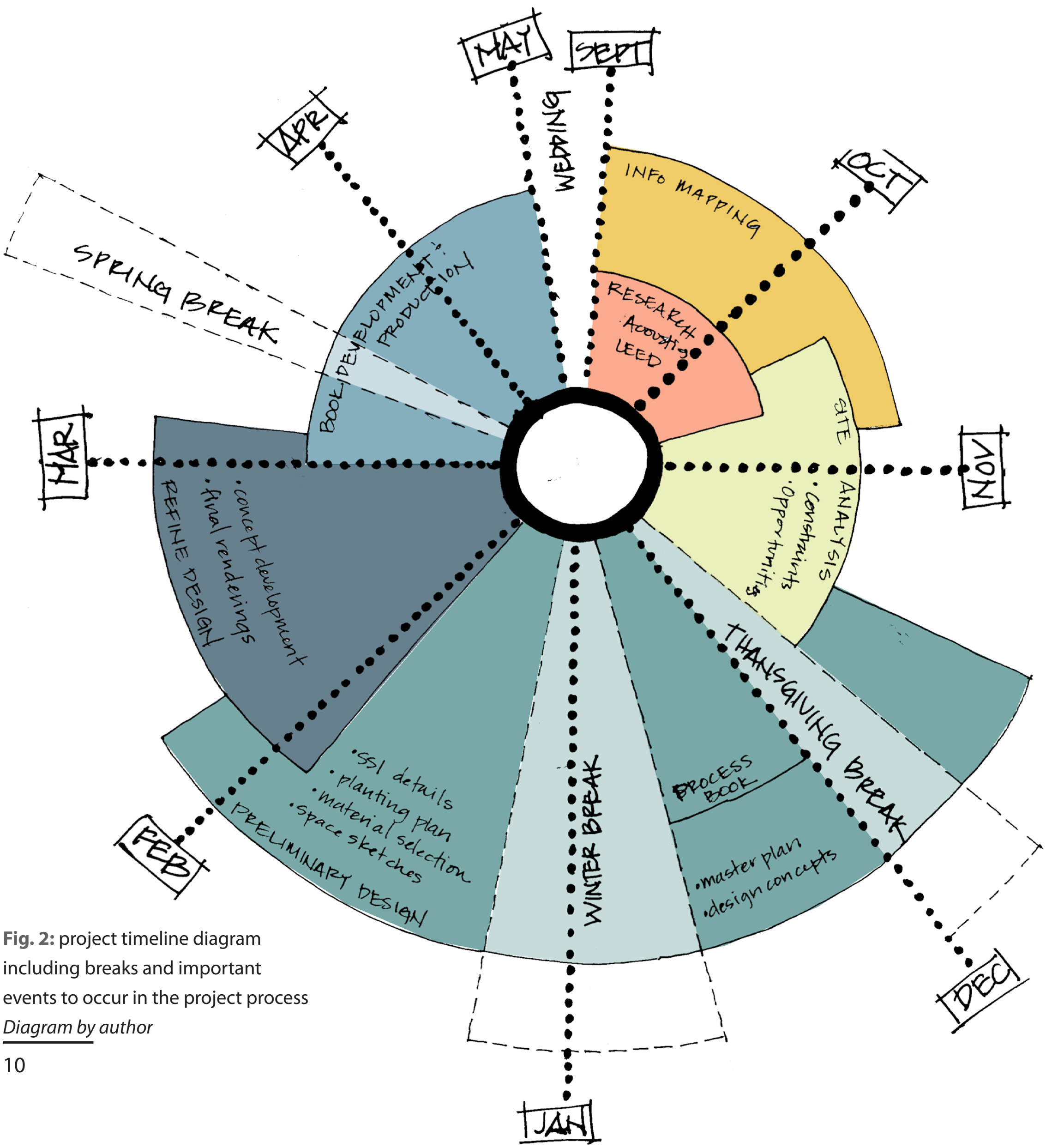


Fig. 2: project timeline diagram including breaks and important events to occur in the project process
Diagram by author

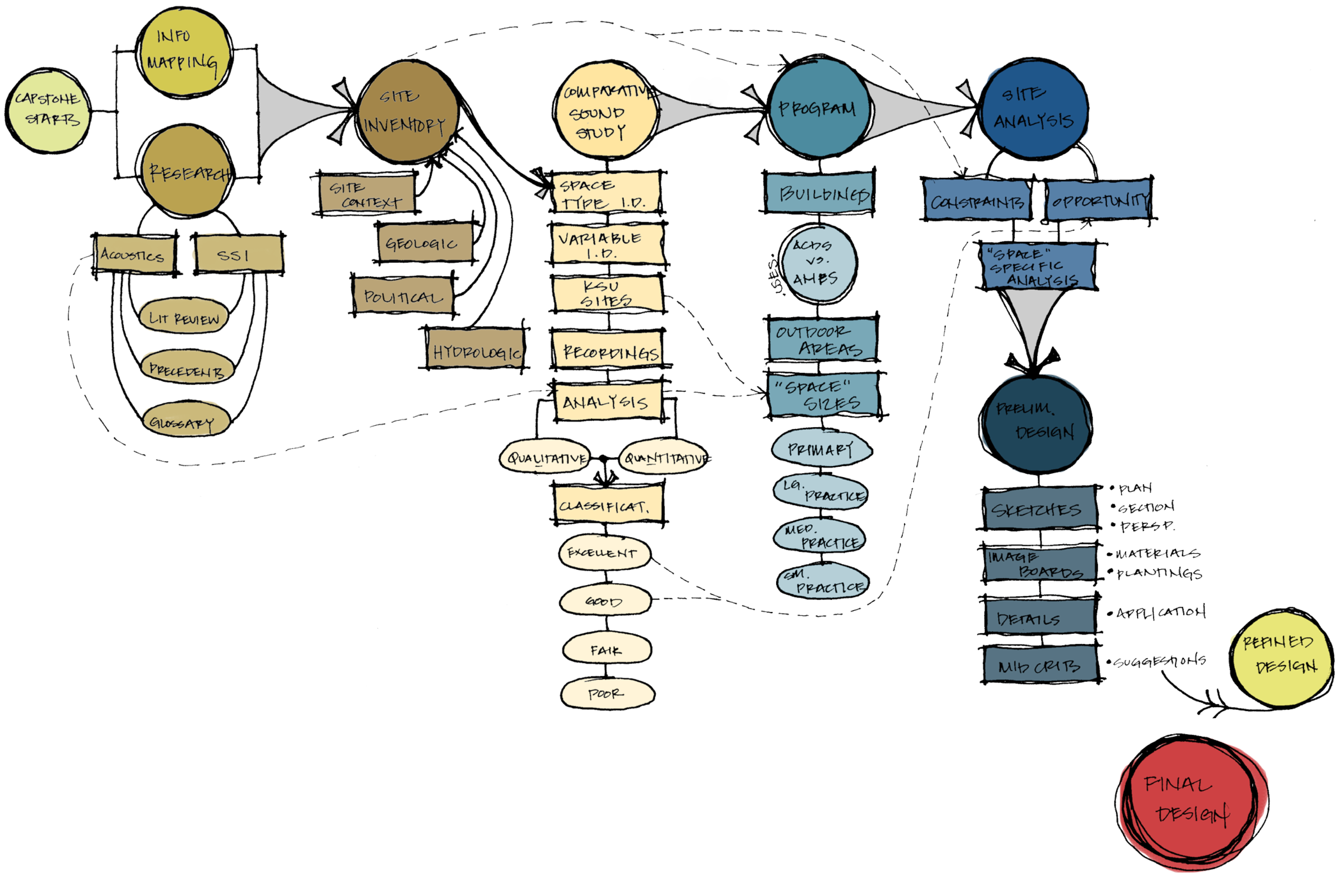
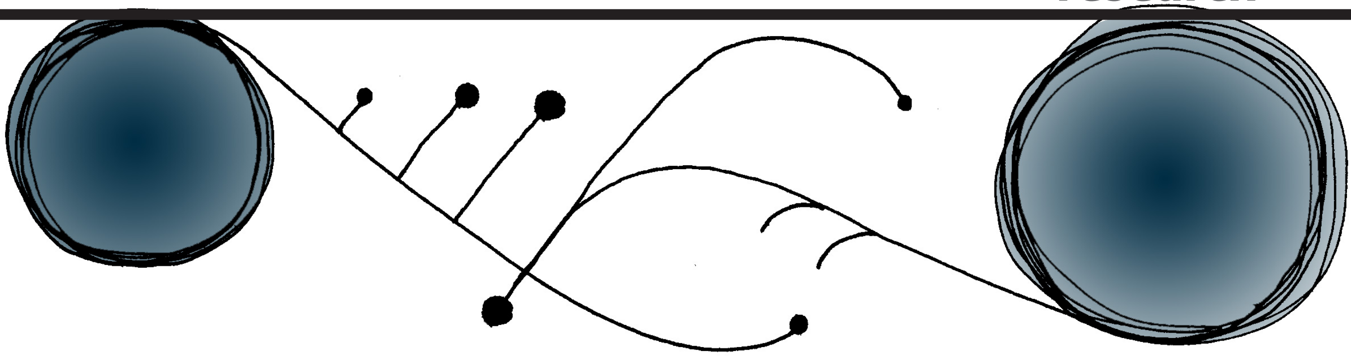


Fig. 3: decision tree diagram showing the milestones and contributing factors to moving forward in the process.
Diagram by author

research



To accomplish the goals established in the thesis, some objectives will be met through in-depth research. The objectives the research addresses include:

- development of an understanding related to the basic principles of the science of sound
- determination of which type of performance space is the best suited to the outdoors
- demonstration of how the science of acoustics is important to the perceptions of music
- determination of the sound propagation potential of certain vegetation types
- expression of the physical and psychological importance of sound in outdoor spaces.

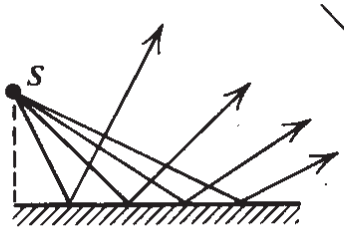
Research is a means of providing clarity to the subject matter of acoustics and sustainability. The two subjects require very different levels of research. There are four (4) primary subjects related to acoustics that are important to understand before moving forward in the design process; some basics of sound, sound in nature, acoustics and music and the importance of acoustics to listeners.

sound basics

In order to design acoustic spaces outdoors, the basic science of acoustics must first be understood. The knowledge of the basic concepts of how sound moves and reacts is essential in making design decisions.

sources of sound

According to Frederick White, once a Professor of Nuclear Engineering, Environmental Engineering and Industrial Liason Scientist to Rensselaer Polytechnic Institute, there are two main sources of sound. A point source is defined as one that produces a spherical sound field and is the most common source (*see Fig 4*). The second is a line source which can be exemplified by a busy highway where sound is being radiated from many vehicles over an extended distance. Sound from this type of source will radiate in a cyclical pattern (*see Fig 5*).



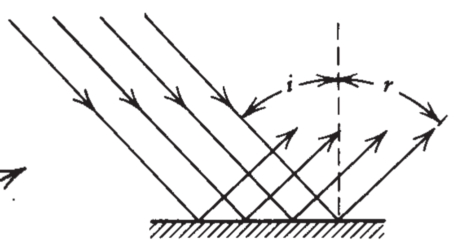


Fig. 4 (left): diagram showing "point" source for sound
Source: White 1975, p.44

Fig. 5: diagram showing "line" source for sound
Source: White 1975, p.44

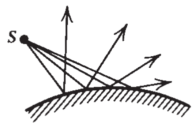
reflection

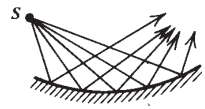
The reflection of sound occurs when the material obstructing the path of sound is not considerably absorbent. The source, type of surface and distance all affect how sound is reflected. There are multiple scenarios described by Frederick White. The first being a distant source reflecting from a plane (or flat) surface (*see Fig. 5*). When working with a single point source, the reflection is distorted based on the shape and orientation of the surface (*see Fig. 4, 6, 7 and 8*).

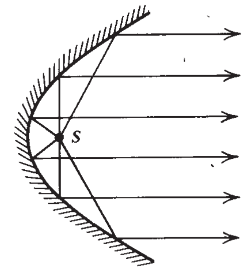
Fig. 6 (left): point source near convex surface
Source: White 1975, p.44

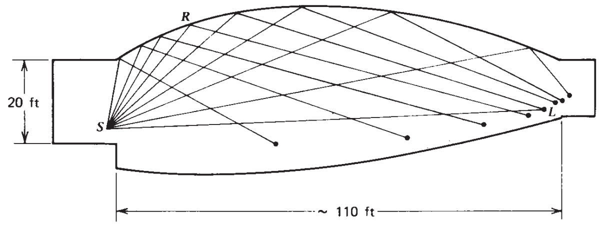
Fig. 7 (middle): point source near concave surface
Source: White 1975, p.44

Fig. 8 (right): point source with parabolic reflecting surface.
Source: White 1975, p.44









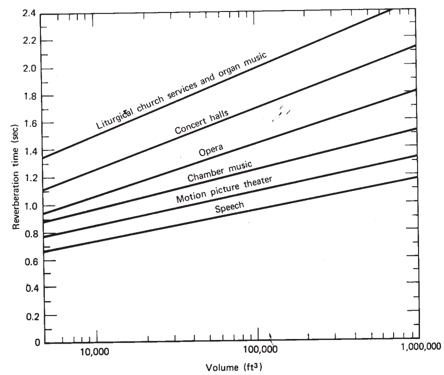


Fig. 9 (upper left): ceiling reflections provide effective sound reinforcement. If the time delay between direct and reflected path is short, the reflected sound will reinforce the direct sound, and the directionality of sound will be preserved.
Source: White 1975, 436

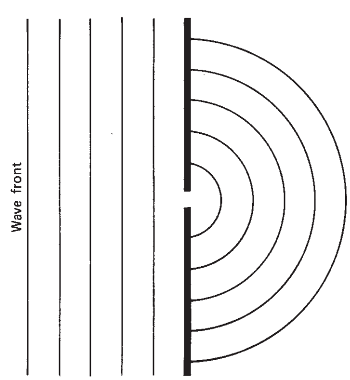
Fig. 10 (upper right): typical reverberation times for various auditoriums and functions.
Source: White 1975, 440

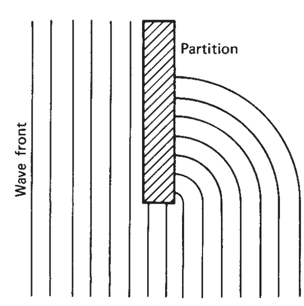
diffraction

Pure reflection of sound rarely occurs because the dimensions of sound waves are influenced by those of typical objects in the environment such as doors, windows and tree trunks, to name a few examples of obstructions. It is for this reason that we typically perceive sound by means of diffraction, "the bending or spreading out of a sound wave after it intersects a protrusion" (White 1975, p.45). Two examples White discusses are a small aperture (*Fig. 11*) and partition (*Fig. 12*).

Fig. 11 (left): diffraction of a sound wave passing through a small aperture.
Source: White 1975, p.46

Fig. 12 (right): diffraction of a sound wave passing by a partition or barrier.
Source: White 1975, p.46





refraction

Refraction is the rotation or twisting of sound due to a change in material type. White describes this example: a balloon filled with carbon dioxide; if a person's ear is positioned on one side of the balloon and a watch on the other, a point can be determined where the tick of the watch is the loudest. Therefore, the balloon acts as a kind of lens similar to the twisting of light through a camera lens (White 1975, p.47). It is because of refraction that some sounds can be heard from great distances (*Fig. 13)*.

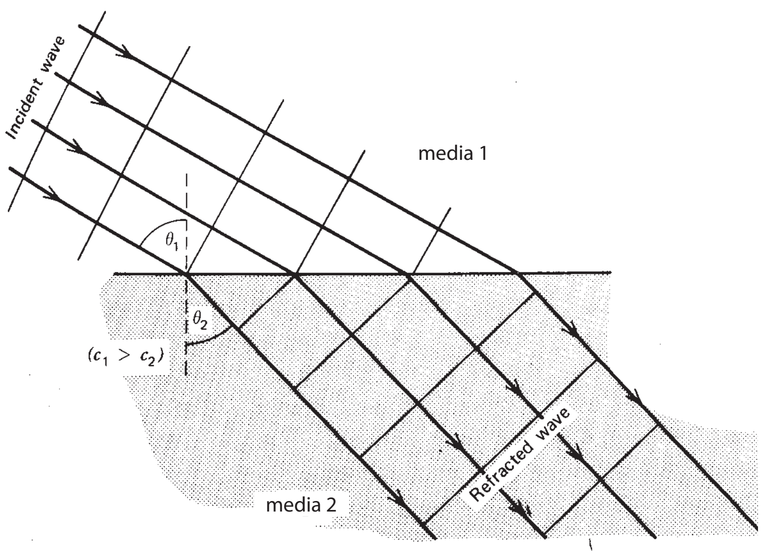


Fig. 13: refraction of a sound wave from one media to another. In the illustration media 1 has a greater velocity of propagation than media 2. *Source: White 1975, p.47*

sound in nature

Certain atmospheric factors profoundly affect the propagation of sound in open air conditions. Whether it is through air absorption, wind, air temperature, or ground cover, sound can be adversely affected. These factors should be considered when designing outdoor spaces for musical purposes.

air absorption

The absorption capacity of air is affected by two main factors made up of more specific factors that can be measured and accounted for when determining the physics of acoustics. The first main factor is classical absorption which is caused by the combination of viscosity, heat conductivity and dissipation of energy due to air molecules (White 1975, p.61). In many cases this can be neglected except when dealing with higher frequencies.

The second main factor affecting air absorption is referred to as molecular relaxation absorption. This factor is dependent on frequency, temperature and humidity. These factors can alter the “brilliance” of a musical piece in an outdoor performance space. Because the Castle Creek Campus sits at a high elevation where the air is thin and rarely humid this does not play a major role in the design of the spaces, but should be considered when applying the standards to other geographical areas.

In more humid parts of the country, air absorption can greatly reduce the clarity and loudness of the sound traveling from its origin.

wind

Wind affects sound by deflecting it from its original path. Common sense and personal experience tells us that "it's easier to hear a distant sound if the sound is traveling with the wind direction" (White 1975, p.63). If wind causes sound to bend upward a shadow region results in which acoustic energy is significantly reduced, thereby lessening the loudness and clarity of the sound source (*Fig. 14*) .

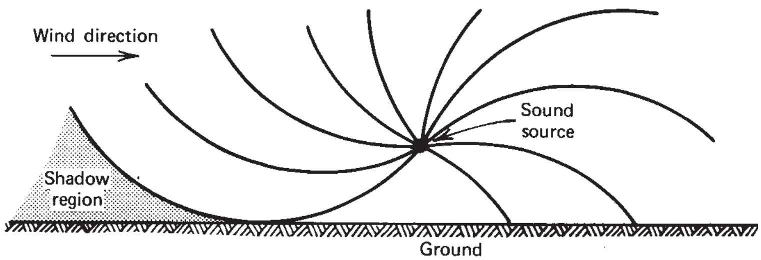


Fig. 14: effect of a wind gradient on sound propagation. The sound waves are refracted by a vertical wind shear, and a "shadow region" can exist where little sound is detected. *Source: White 1975, p.64*

temperature

Temperature also has a profound effect on sound propagation. The velocity of sound decreases with a decrease in temperature. Therefore, waves radiating from a sound source will be bent upward. This also creates a shadow region where sound is more difficult to hear (*Fig. 15*).

The opposite effect happens when cooler air is close to the ground and the air temperature increases with altitude. The top of the wavefronts travel faster than the bottom of the wavefronts resulting in the sound bending toward the ground (*Fig. 16*). The downward bending typically occurs in winter and allows sounds to be heard from much greater distances, particularly across water.

According to White, when the sound is bending downward "over a lake and on a quiet day, it is possible to understand speech at distances up to half a mile or more" (White 1975, p.66).

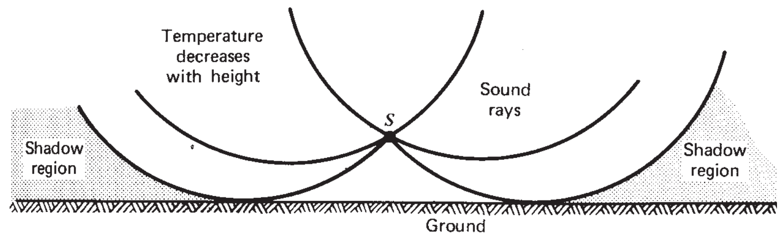


Fig. 15: upward bending of sound rays with normal temperature gradient.
Source: White 1975, p.67

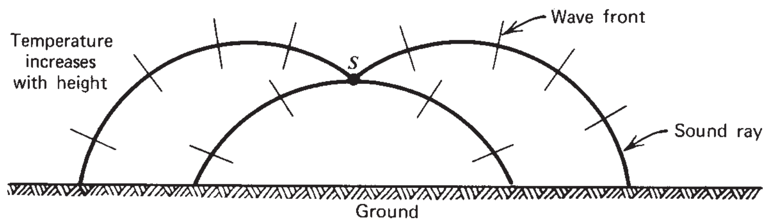


Fig. 16: downward bending of sound rays because of temperature inversion.
Source: White 1975, p.67

ground cover

Sound moving near the ground can be lessened in loudness by shrubs, trees and to a smaller extent, soil. The leaves, trunks and stems of trees cause some of the sound traveling to scatter, altering the direct path of the sound waves. White shows the effect of dense evergreen trees mixed with heavy ground cover on noise reduction in *Fig. 17*.

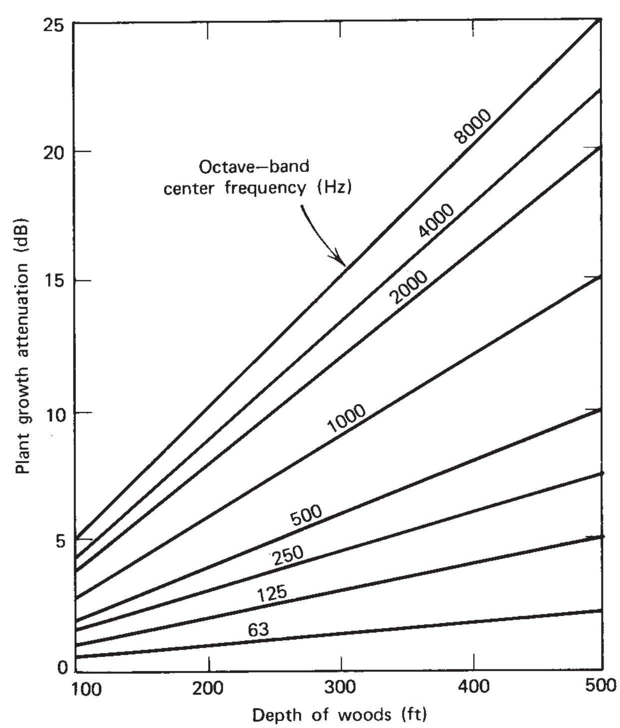


Fig. 17: approximate attenuation of sound because of dense woods having a visibility penetration of 70 to 100 feet.
Source: White 1975, p.71

acoustics + music

Acoustics present a much less subjective method of observing and analyzing music related to listening experience. The science examines acoustic criteria for music as well as the organization of structures for performance spaces in a manner that can both inform and guide the future design of performance and practice spaces in a natural context.

acoustic criteria for music

There are some acoustic criteria specifically for music. "For major symphonic works, a *live* or reverberant auditorium is essential" (White 1975, p.436). There are several qualities that characterize the ideal concert hall:

- *Uniform Loudness* - the multiple reflections will cause the sound intensity to be sustained in the more remote sections of the enclosure, and help provide a proper ratio of direct to reflected sound closure to the stage area. Due to factors such as wind and temperature the direct sound from musical instruments lessens as it moves away from the sound source. This means that as a musical note is carried across an audience, the loudness of that note can diminish up to one eighth the original level from the source to the back of the audience. The precise amount depends on the conditions of the space as shown in *Fig. 18-23.*

- *Enhancement of Bass and Treble* - This can be achieved through the proper choice of materials, those that have a very low sound absorption coefficient. The enhancement of bass will add warmth to the composition. The brilliance of the treble can be enhanced by the "strategic placement of sound reflecting panels" (White 1975, p.437).

- *Fullness of Tone* - results from the blending of a tone with preceding and subsequent tones. The fullness or breadth of tone is especially desirable in many musical passages, and this quality is quite distinct from the sensation of loudness. Fullness can be enhanced by increasing the reverberation time.

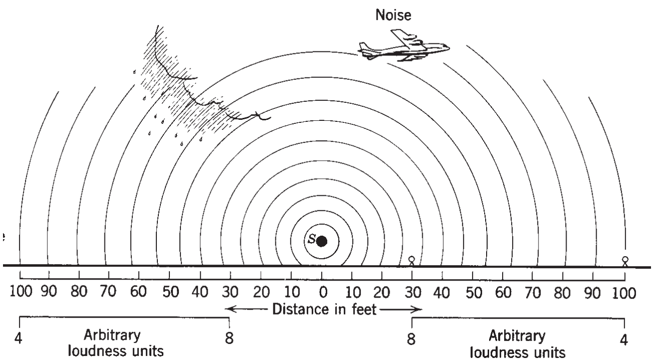


Fig. 18: sound in an open field with no wind.
Source: Beranek 1962, p.17

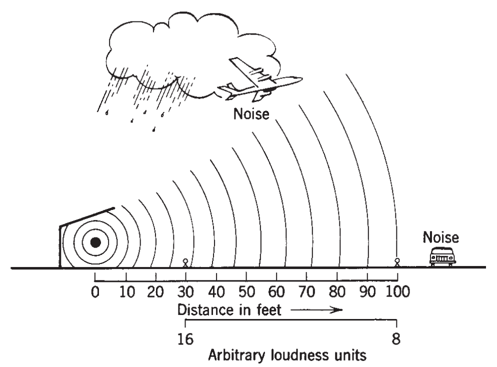


Fig. 19: sound from an orchestra enclosure in an open field with no wind.
Source: Beranek 1962, p.18

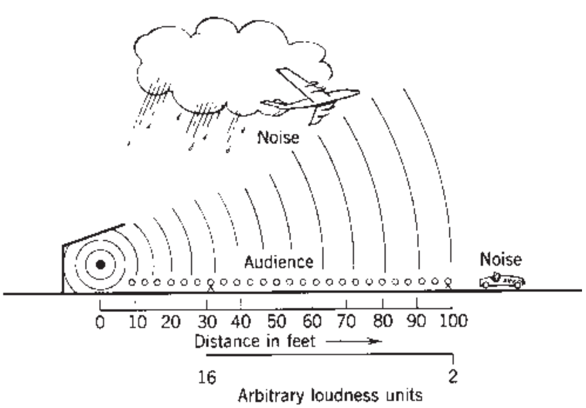


Fig. 20: sound from an orchestra enclosure with an audience.
Source: Beranek 1962, p.19

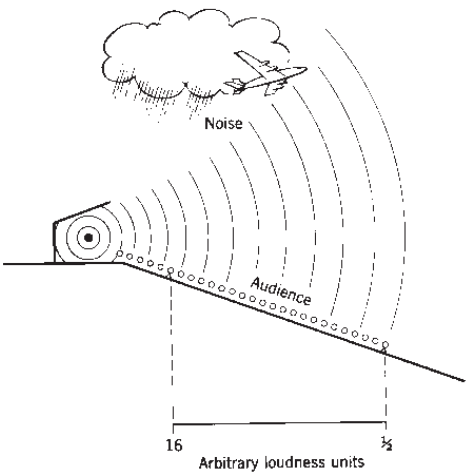


Fig. 21: sound from an orchestra enclosure and audience sloping downward, no wind.
Source: Beranek 1962, p.20

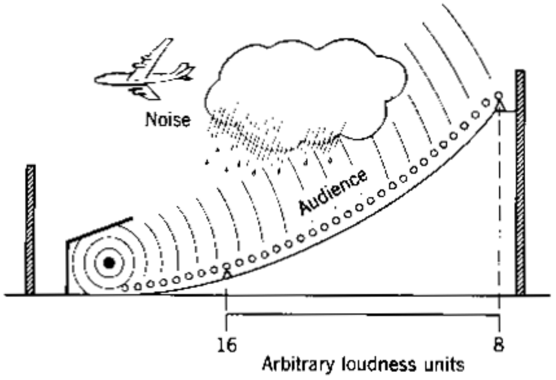


Fig. 22: the loudness of a sound is enhanced at the rear of the audience by sloping the seating upwards.
Source: Beranek 1962, p.21

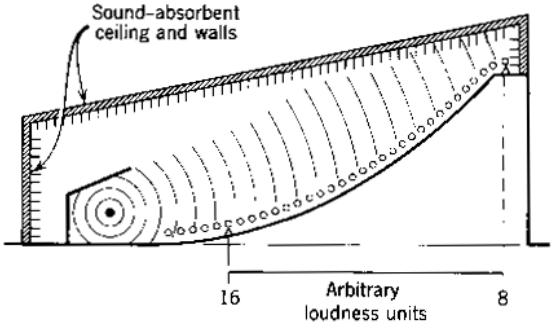


Fig. 23: enclosing the orchestra enclosure and the audience will eliminate ambient noise and weather.
Source: Beranek 1962, p.21

- *Range of Crescendo* - The listener under ideal conditions, can sense a single instrument at 30dB and hear an entire orchestra grow into a *double forte* (90dB). It is the reverberation the audiences feels after such chords that supports the emotional impact of music.

- *Diffusion of Sound* - The sound is separated and sent in all directions of the hall. This is a desirable result of reverberation because in an ideal hall, music literally fills the hall.

- *Intimacy* - A small space has visual intimacy. A space has acoustical intimacy when the music sounds as though it is being played in a small space. This perception of intimacy is caused by the initial-time-delay gap, or the interval between the sound that arrives directly at his or her ear and the first reflection that arrives there from the ceiling or the walls as shown in *Fig. 24*.

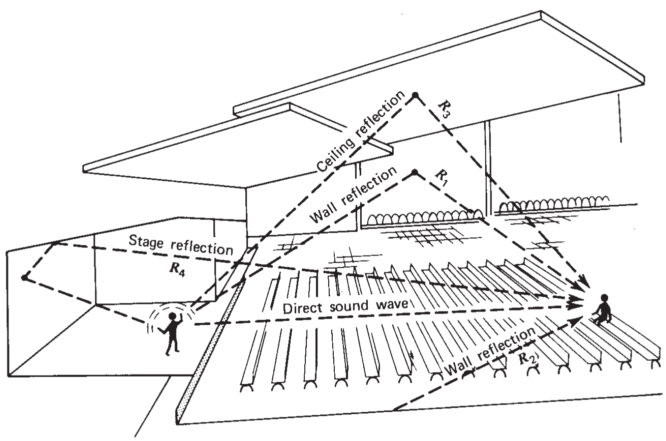


Fig. 24: paths of direct and reflected sound in an auditorium.
Source: White 1975, p.67

organization of structures for performance spaces

There are three main categories of venue organization; rectangular, horseshoe, and fan shaped. Appleton provides some basic information on precedents in open air performance situations. This work is useful primarily due to its classification of different layouts for concert halls. He provides theories as to why certain halls are shaped differently and what this does to the sound quality of the hall. He also explains the different types of musical performances. He perceives that there are specific needs for each type that should be addressed when designing a performance hall. He then uses these terms, as well as their location and use (i.e. choral, jazz, orchestral, rock concert...), to divide and classify the types of performance halls.

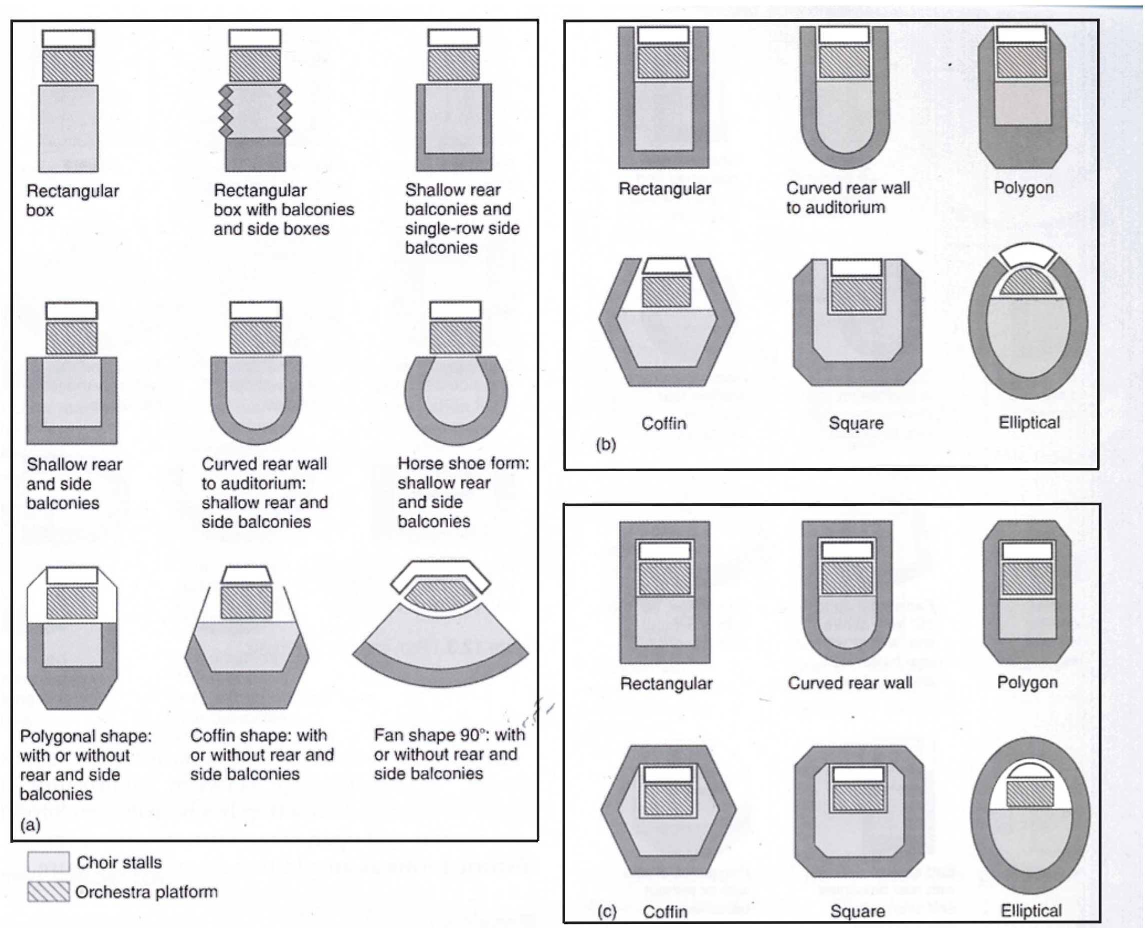


Fig. 25: Orchestral and choral music plan arrangements for each of the standard organizations (rectangular, horseshoe and fan).
(a) Single direction relationship.
(b) Audience partially surrounding platform, with or without rear and side balconies.
(c) Audience surrounding platform, with or without rear and side balconies.

Diagrams Ian Appleton, 2008

importance to listeners

According to White, the physiological and psychological effects of sound provide evidence to support design decision making on the campus. It has been scientifically proven that auditory stimuli induce responses in the human body. For instance:

- *Blood Circulation* - When a listener hears a "reasonably short, intense sound, a general constriction of the peripheral blood vessels with a reduction in peripheral blood flow has been observed." Research in Germany and Russia have shown that workers in particularly noisy environments have a higher percentage of circulatory, digestive and metabolic difficulties (*Fig. 26, 27*).

- *Skin Resistance* - Noise has been shown to reduce the resistance of the skin to electric current.

- *Muscle Tension* - For a steady noise level of 90dB, increased tension in the muscles was apparent. Also, the subject's ability to respond to a simple task was adversely effected.

- *Breathing* - Changes in breathing patterns have been noted for intermittent sound levels.

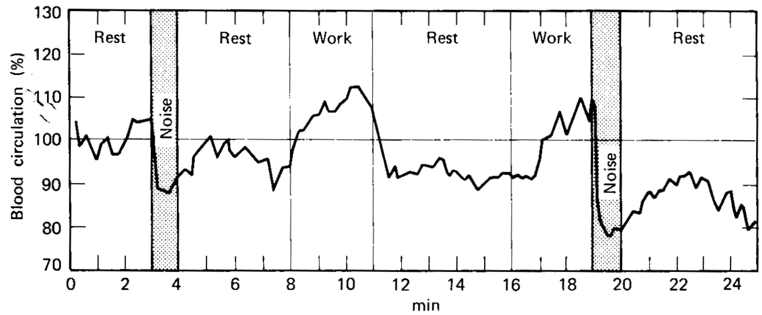


Fig. 26: the effect on the blood circulatory system, attributed to periods of rest, work, and noise.
Source: White 1975, p.462

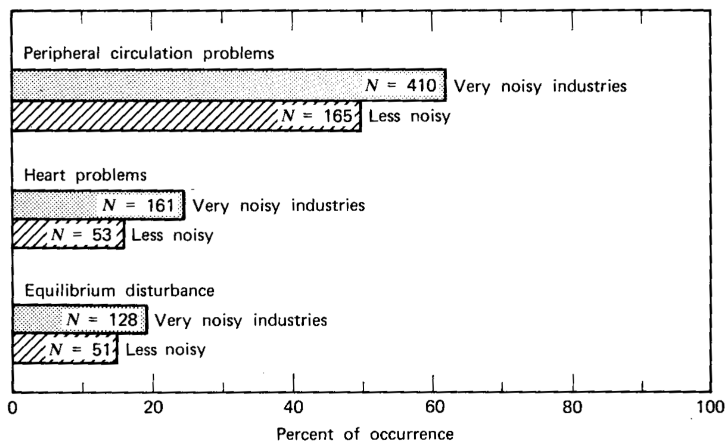


Fig. 27: differences in physiological responses among German workers
Source: White 1975, p.462

Noise and sound can alter the physiological habits of humans. White references scientific evidence and related literature including:

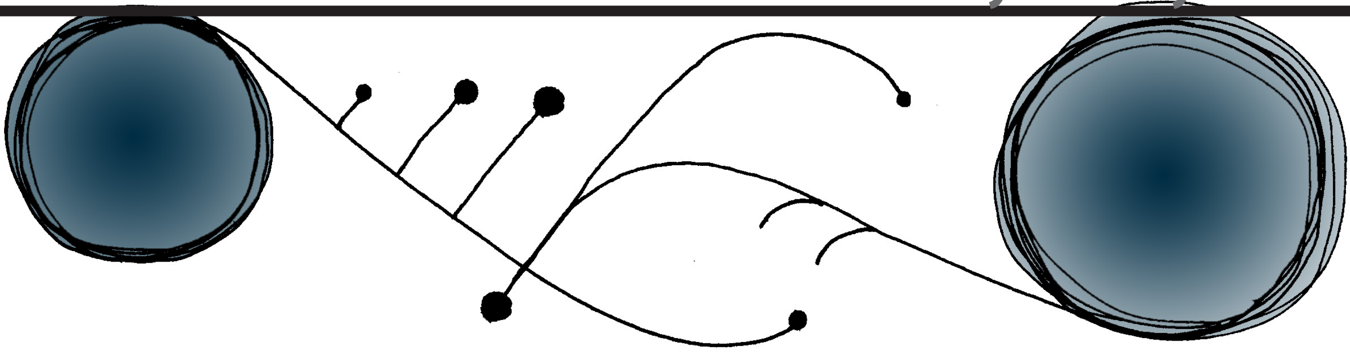
1. J.D. Miller, *Effects of Noise on People*, U.S.E.P.A., National Technical Information Service, Springfield, Va., 1971, pp. 127-129.

2. K. D. Kryter, *The Effects of Noise on Man*, Academic, New York, 1970, p. 508.

3. R. C. Davis, A. M. Buchwald, and R. W. Franklin, *Phychol. Monograph*, 69, No. 20, 1 (1955)

Acoustics is a science closely allied to physics, more so than landscape architecture. However, there are some fundamental principles that can be applied by a landscape architect in the early stages of design to produce the best possible design solution. Developing an understanding of how sound interacts, how that interaction occurs in nature, how acoustics relates to music, and how sound affects the human body and psyche guides the inventory and analysis, and later the design of these performance spaces.

site inventory + analysis



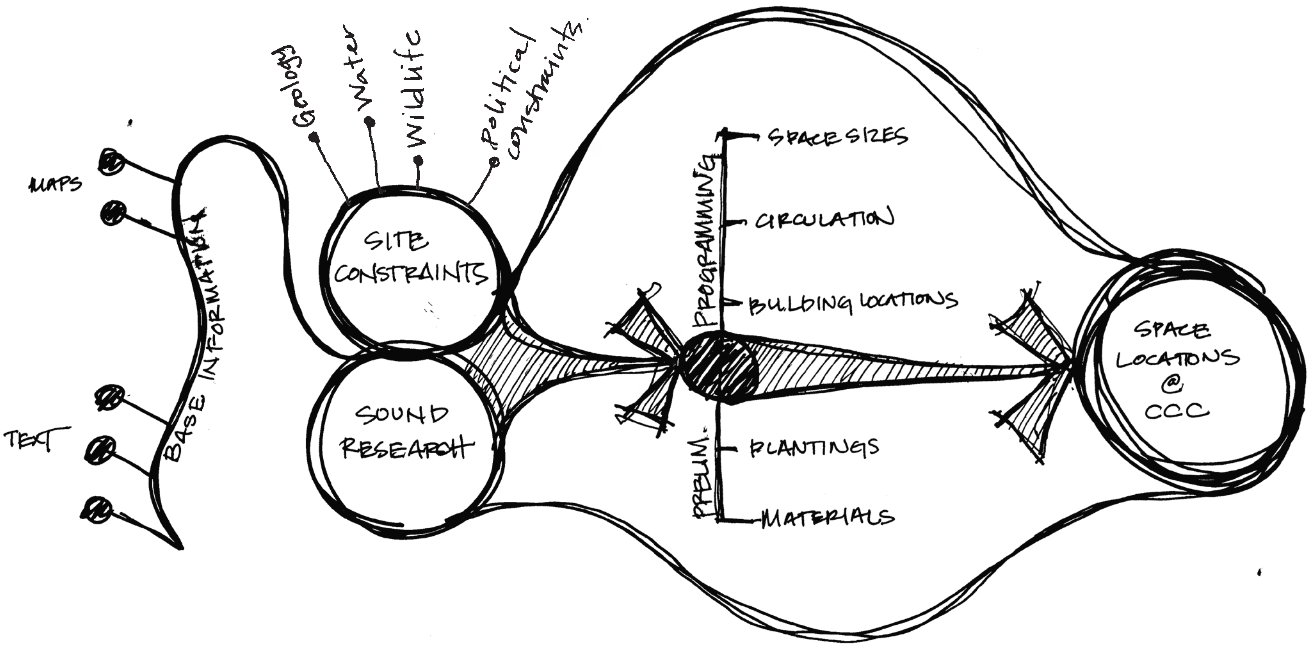
introduction

There are multiple factors affecting the development potential for the Castle Creek Campus. The following inventory and analysis of the site includes observations of the underlying geology, water, wildlife, political constraints and acoustic characteristics. These factors will impact the conceptual framework and design of the Campus.

The process for inventory and analysis (*Fig. 28*) is developed from the acoustic research. Much of the base information in the form of text and maps provide a starting point for identifying and analyzing factors researched through the acoustic literature. These maps and technical text lead to identification of constraints on the site which affect development of the Campus, in a practical sense. A sound study was developed to test some of the acoustic standards previously researched in a way that was relevant to the Castle Creek Campus. The results of this study assisted in then developing a preliminary program. Applying that program to the site in a manner that solves site constraints and capitalizes on site opportunities is the end goal of analysis.

The design for redevelopment of the Castle Creek Campus is based on acoustic quality and sustainability of the spaces; and the Campus master plan. These factors were inventoried separately then analyzed to see where constraints and opportunities overlapped. In order to narrow and structure the inventory and analysis process, some of the previously established goals and objectives were used as a guide. Other goals and objectives are addressed in other steps in the design process.

Fig. 28: process diagram for site inventory and analysis.



objectives

Because this is a musical institution which is set in a naturally beautiful environment it makes sense to bring the musical experience for both the students and the patrons into the landscape.

Goal 1 - Bring small performance venues outdoors without losing acoustic quality.

- Objective 1: define “good” acoustics in relation to the Castle Creek Campus.
- Objective 2: Create a number of intimate spaces for students to practice determined by the program required by the clients.
- Objective 3: Determine which vegetation types best propagate sound.

The inclusion of SSI guidelines is important to the quality of the Campus. Remaining sensitive to the natural systems increases the longevity of the Campus redevelopment and adds to the natural surroundings in a manner that enhances, not destroys.

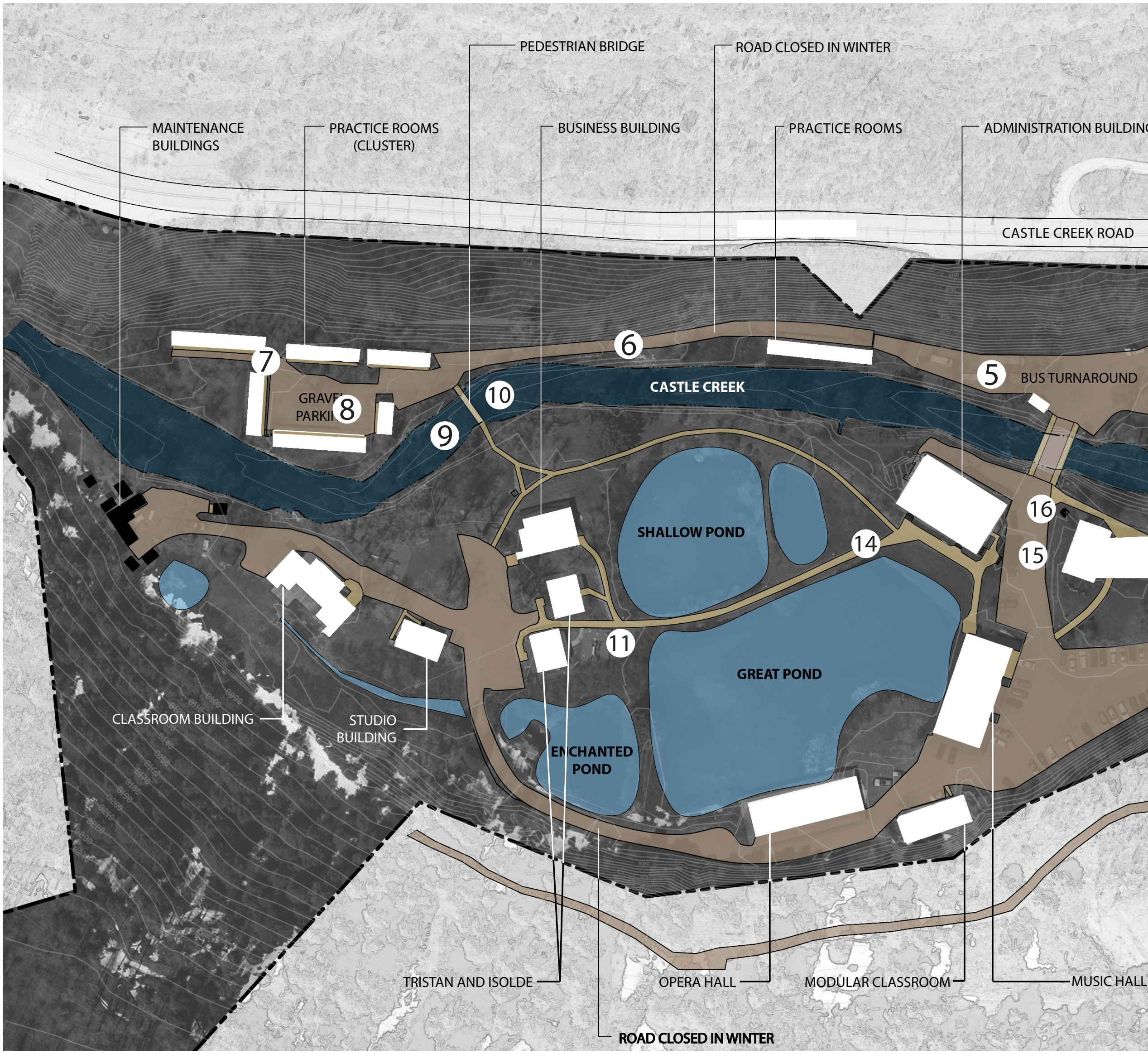
Goal 3 - Incorporate SSI guidelines into the placement and design of spaces and the Campus in general.

- Objective 1: preserve the natural character of the site both architecturally and site-wise.
- Objective 2: enhance and/or preserve the water quality of Castle Creek.
- Objective 3: alleviate development pressure on the site by strategically reducing program requirements (in terms of building square footage).
- Objective 4: use native vegetation, requiring less irrigation.
- Objective 5: protect the extent and quality of riparian areas and wetlands.
- Objective 6: identify problem areas containing poor hydrologic cycles and rectify in master plan.

inventory

context

The Castle Creek Campus (CCC) is situated in the North-Central Highlands and Rocky Mountain Section of the Southern Rocky Mountains Steppe - Open Woodland - Coniferous Forest - Alpine Meadow Physiographic Province. Elevation of the Campus ranges from approximately 8,051 to 8,336 feet. Castle Creek, a perennial stream, runs southwest to northeast through the length of the Campus (*Fig.29*). Keno Gulch, an intermittent stream, flows southeast to northwest across the Campus to its confluence with Castle Creek (Lowsky 2007, p5). The Campus although beautiful is surrounded by hazardous site conditions which effect the development potential of certain areas. The primary limiting factors are geologic, political, hydrologic or wildlife related. The mapped information comes from Schmueser Gordon Meyer Inc., the engineering firm for the project. The synthesis of these factors effect the feasibility and the proposed master plan of the property.



PEDESTRIAN BRIDGE
ROAD CLOSED IN WINTER
MAINTENANCE BUILDINGS
PRACTICE ROOMS (CLUSTER)
BUSINESS BUILDING
PRACTICE ROOMS
ADMINISTRATION BUILDING
CASTLE CREEK ROAD
6
7
GRAVEL PARKING
8
10
9
CASTLE CREEK
5
BUS TURNAROUND
16
15
14
SHALLOW POND
11
GREAT POND
ENCHANTED POND
CLASSROOM BUILDING
STUDIO BUILDING
TRISTAN AND ISOLDE
OPERA HALL
MODULAR CLASSROOM
MUSIC HALL
ROAD CLOSED IN WINTER

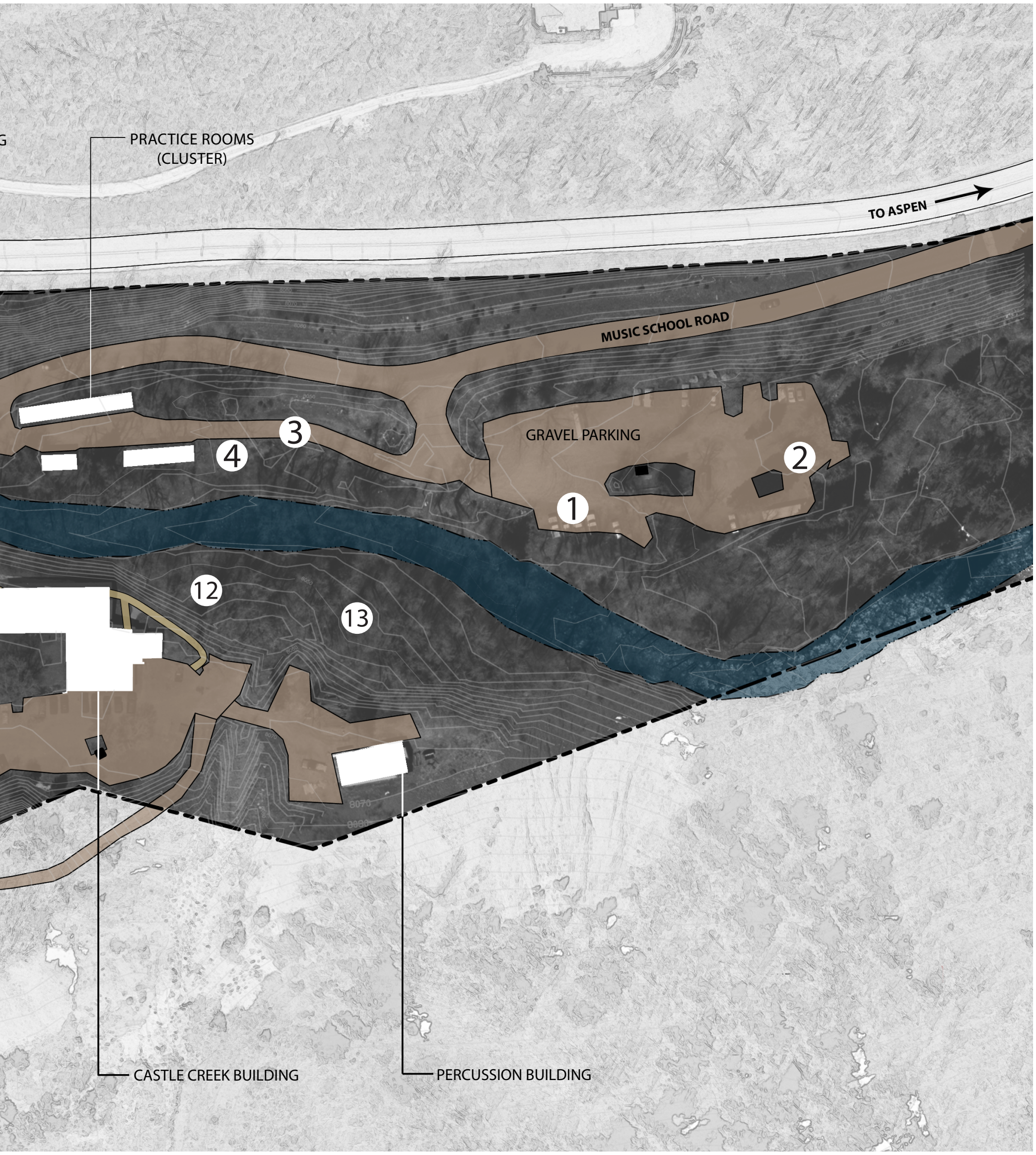
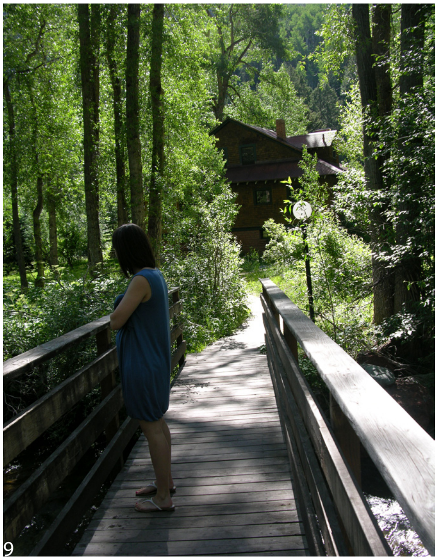
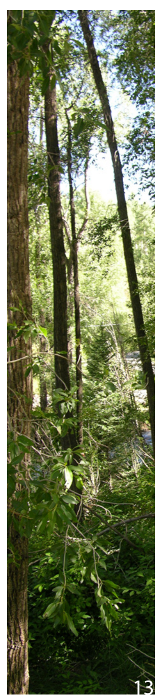


Fig.29: map of existing conditions which shows building and pond names of the CCC. The numbers relate to the location of the following site photographs.

Fig. 30: site photos of the Campus in late summer while the Aspen Music Festival and School is in session.





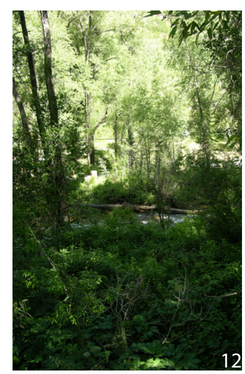


Fig. 31: site photos of the Campus in late summer while the Aspen Music Festival and School is in session.

geologic conditions

The geologic conditions of the Campus are common to the Rocky Mountain Region. The site is limited by ***thirty percent (30%) or greater slopes,*** rockfall areas, moderate to severe avalanche areas and a large debris flow area. Nearly one half of the land area falls within the 30% or greater range. This makes avoiding these areas altogether unfeasible for the desired program requirements (*Fig. 32*).

The ***rockfall*** is limited to primarily the southwestern and mid eastern areas of the site. Much of what has already fallen onto the site is from construction operations occurring to the south off of Castle Creek Road as seen in *Fig. 33*. According to the geotechnical report, any buildings in these areas should be built to withstand an "impact force from a rolling boulder of 580 lbs. The impact force from the rolling boulder from a 40-foot high slope was evaluated assuming a 2-foot diameter rock rolling at a impact velocity of less than 27 feet per second" (Yeh and Associates, Inc., 2007, p7).

Fig. 32: near the existing percussion building extremely severe slopes create rock fall conditions which pummel the small building in the winter time.

Fig.33: boulders ranging from 3" to 2' diameter are scattered along the very steep slopes in the south west corner of the site.

The ***avalanche*** areas range from moderate to severe forecasts. Moderate is defined as "areas of unstable snow. Avalanches are possible on steep, snow-covered open slopes and gullies" (Williams, 1988, p1). Primarily this occurs on the western facing slopes of Aspen Mountain on the east edge of the CCC property. Severe is defined as "mostly unstable snow. Avalanches are likely on steep snow-covered open slopes and gullies. (Williams, 1988, p1)" It is the recommendation of the geotechnical engineer not to disturb severe avalanche areas. In addition, if moderate avalanche areas are to be disturbed they should be reinforced to protect the development from damage.

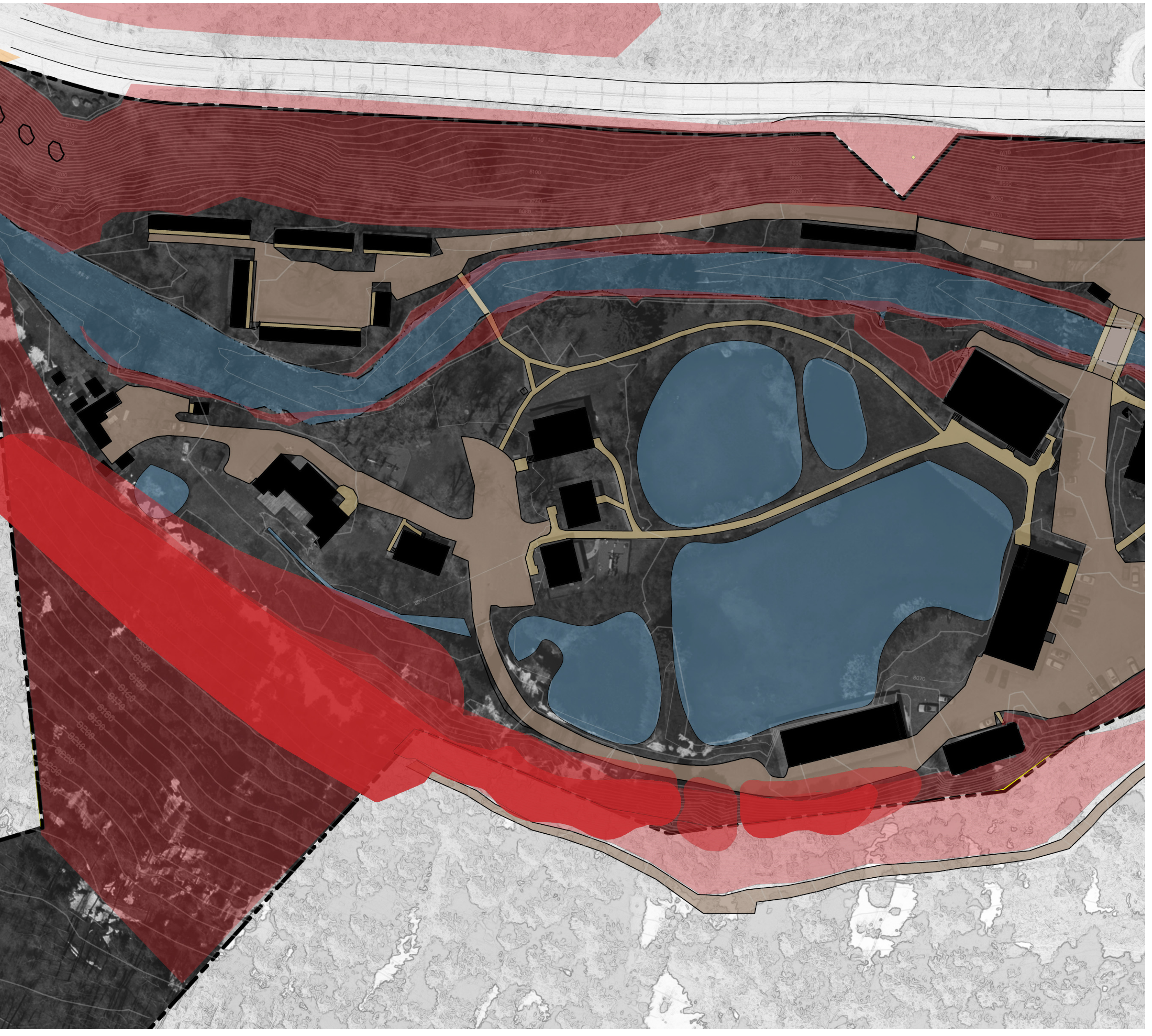
The ***debris flow*** area is the result of Keno Gulch which comes down the west side of Aspen Mountain. The gulch is dry most of the year, as been designed by Schmueser Gordon Meyer Inc. and will be channelized alleviating overflow danger during the snow melt season in the spring. The highlighted area should be free from buildings. Roads and parking are possible at the bottleneck portion of the gulch (*Fig. 34, 35*). A letter by Mr. Arthur Mears, P.E. provided the following debris flow characteristics for the elevation at the mouth of Keno Gulch:

- width — 15 to 20 feet
- depth — 7 to 10 feet
- velocity — 10 to 20 feet per second
- maximum particle size — 3 feet

Based on the background information provided by the project civil and geotechnical engineers it is apparent that approximately one half of the property is undevelopable.

Fig.34: the Keno Gulch is insufficient for current runoff quantities. Water runs across the roadway, hence its seasonal use.

Fig.35: view of the gulch coming down the mountainside. Primarily current side slopes are large rocks or small boulders.



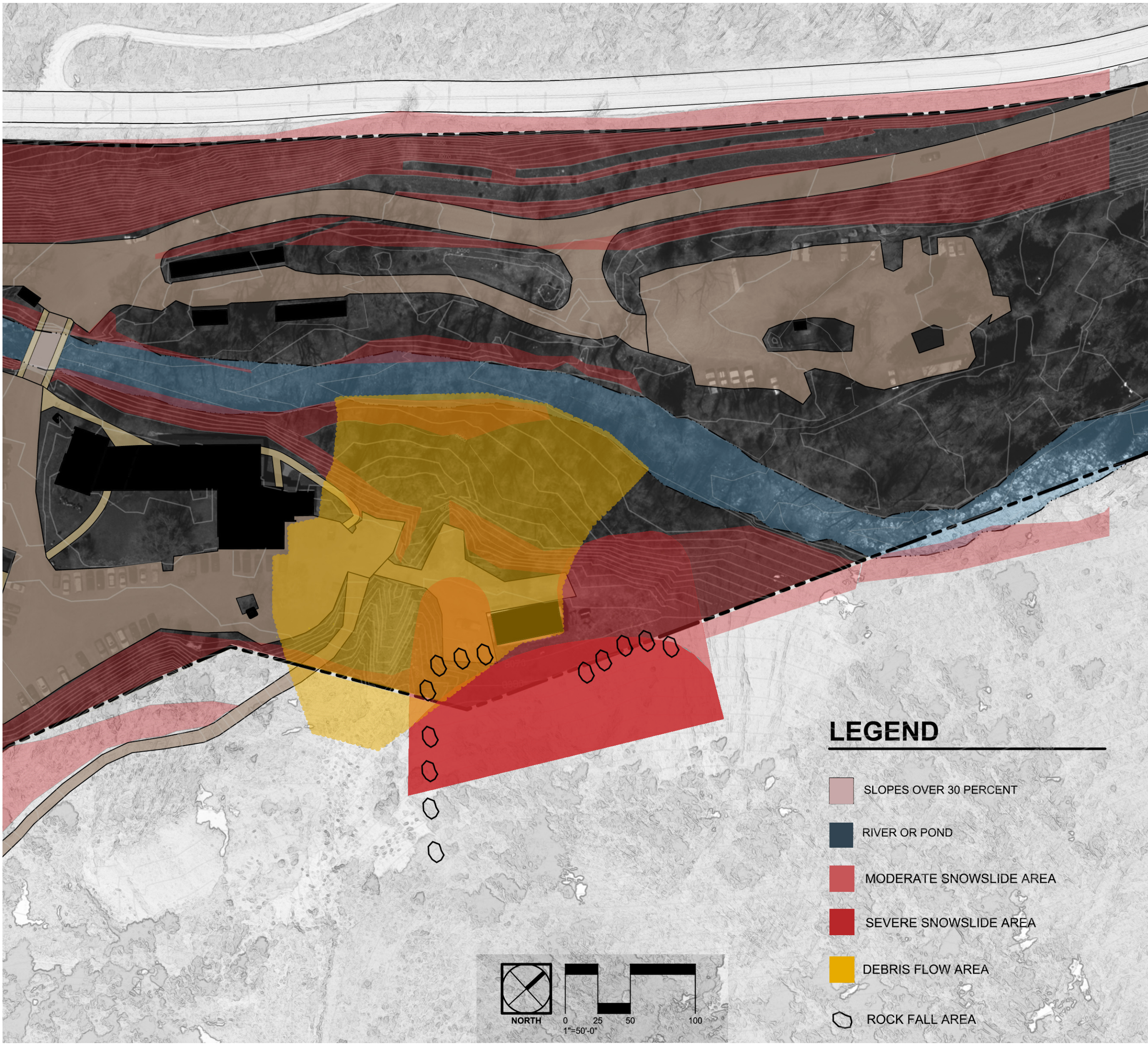


Fig. 36: map of the geologic constraints on the Castle Creek Campus.
Adapted from Design Workshop Inc. 2008

political constraints

Historic Buildings

There are two buildings on the Campus which are on the national registry of historic buildings and therefore must be preserved and/or restored. These buildings are the Administrative Building (*Fig. 37*) and the Business Building (*Fig. 38*). Both add aesthetic value to the Campus displaying the architectural character of the region.

Fig. 37: the Administration Building on the Castle Creek Campus

Photograph Suzanne Richman, DesignWorkshop Inc.

Fig. 38: the Business Building on the Castle Creek Campus

Photograph Suzanne Richman, DesignWorkshop Inc.

water and wildlife conditions

There are multiple hazards associated with the hydrology on the site due to the creek which splits the site into two. These considerations are the creek's floodplain, the rich riparian habitat and wetland areas. Due to Pitkin County regulations there can be no new building within the creek's floodplain. In addition there is a strict mitigation requirement for all disturbed riparian habitat and wetlands. Ideally, these areas should be avoided, but due to the particularly small area of the property and required program that is unlikely (*Fig. 39*).

Floodplain

The floodplain is a hazard which must be respected. Under no circumstances can development take place within the floodplain. It should be easy to avoid given its close proximity to the creek in most locations.

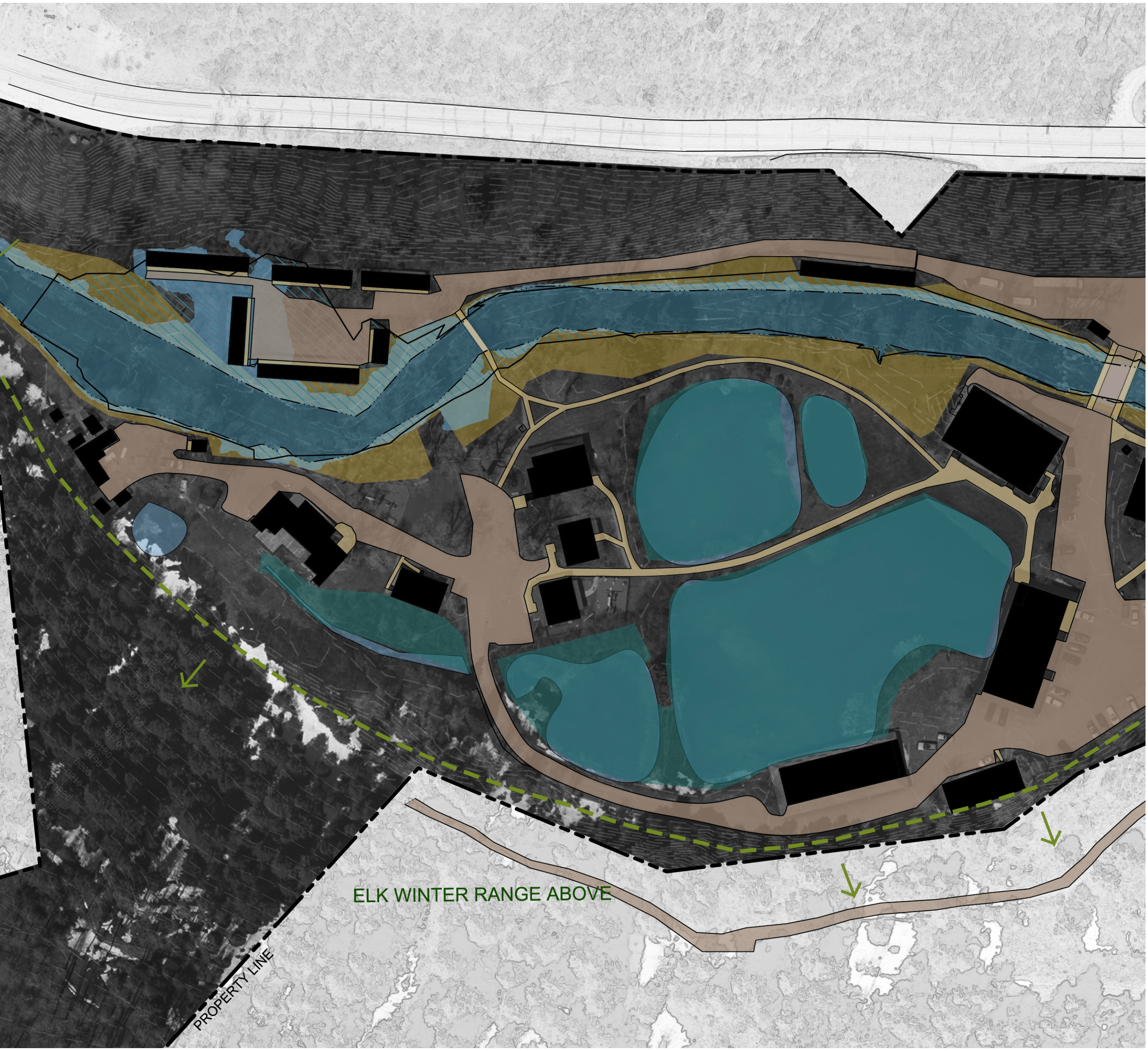
Riparian Habitats and Wetland Areas

Riparian areas are defined by the LUC as:

> *"…plant communities contiguous to and affected by surface and subsurface hydrologic features of perennial or intermittent lotic and lentic water bodies (rivers, streams, lakes, or drainage ways). Riparian areas have one (1) or both of the following characteristics: a) distinctly different vegetative species than adjacent areas, and b) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Riparian areas are often transitional between wetland and upland."*

The areas are regulated by the LUC and require a buffer of 100 feet from the high water line of perennial and intermittent streams such as Castle Creek and Keno Gulch. This regulation can, however, be reduced to 20 feet if the applicant demonstrates that this reduction will not result in a reduction in the quality of the riparian or wetland habitat. Coincidentally, Design Workshop did obtain such a reduction for this site due to the existing development which occurs within the 100 foot buffer zone (Lowsky, 2007 p8).

The natural riparian community is described as Narrowleaf Cottonwood - Colorado Blue Spruce/Thinleaf Alder Riparian Woodland with Engelmann Spruce present but not as common as Blue Spruce. Understory riparian plant species used to delineate the riparian habitat include: (*see Table 1*).


ELK WINTER RANGE ABOVE
PROPERTY LINE

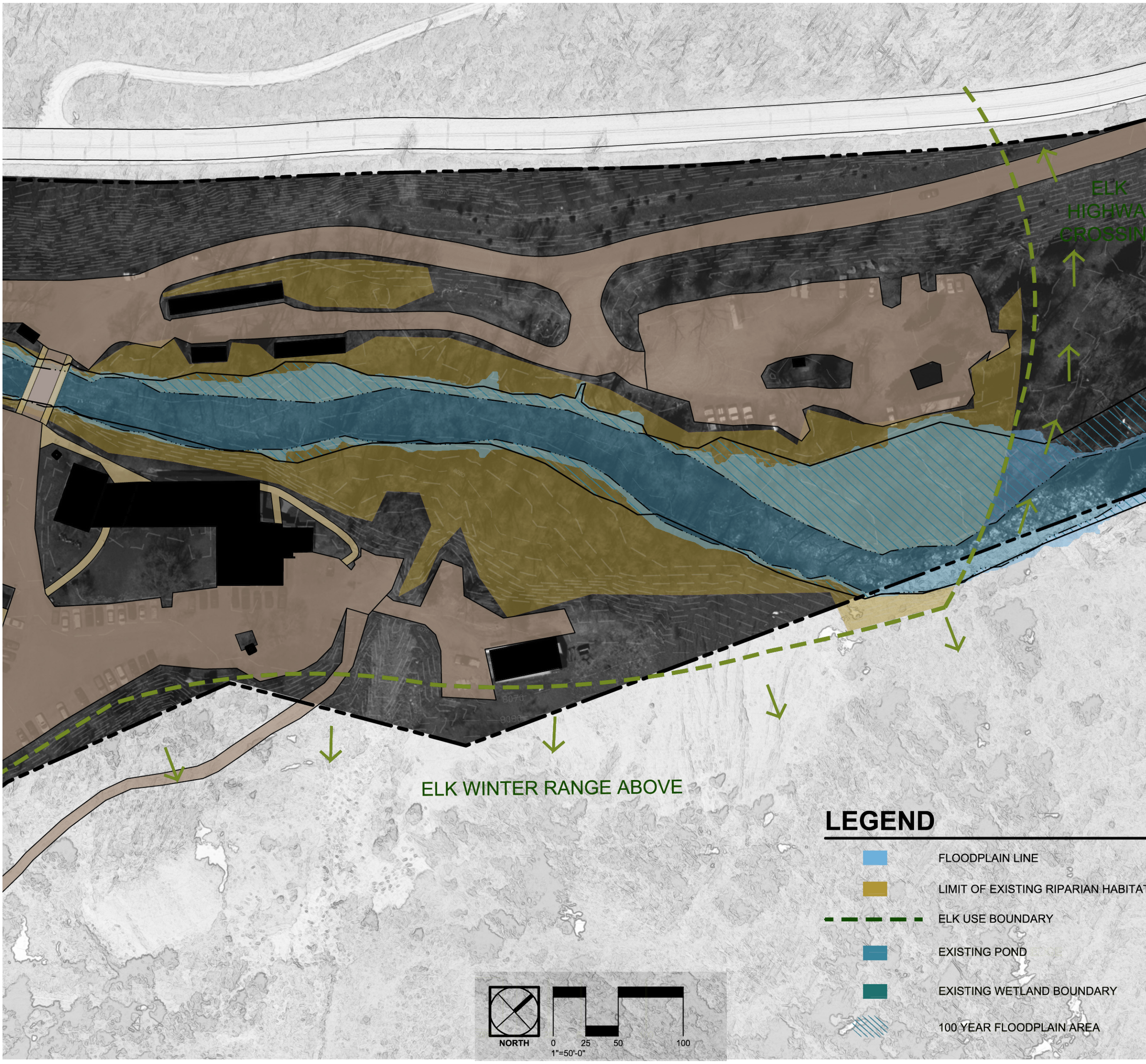


Fig. 39: map of the water and wildlife constraints on the Castle Creek Campus.
Adapted from Design Workshop Inc.

Common Name	*Scientific Name*
American vetch	*Vicia americana*
Baneberry	*Actaea rubra* subsp. *Arguta*
Cow parsnip	*Heracleum spondylium* var. *lanatum*
Field horsetail	*Equisetum arvense*
Willows	*Salix spp.*
Mountain Maple	*Acer glabrum*
Muttongrass	*Poa fendleriana*
Redosier dogwood	*Cornus sericea*
Rocky Mountain columbine	*Aquilegia saximontana*
Starry false Solomon's seal	*Maianthemum stellatum*
Stinging nettle	*Urtica gracillis*
Twinberry honeysuckle	*Lonicera involucrata*
Twisted-stalk	*Streptopus fassettii*
Wax currant	*Ribes cereum*
Whitestem gooseberry	*Ribes inerme*

Table 1: native riparian vegetation on the property.
Source Colorado Wildlife Science, LLC

The Campus does contain naturally occurring riparian areas which are made up of varying quality and functional values. Colorado Wildlife Science, LLC recommends the mitigation ratios (in caliper inches) of:

Low	1:1
Moderate	1.25:1
High	1.5:1

Mitigation requires that the planting design establish areas of native riparian vegetation which contribute to the quality of water entering the creek and the stability of the diverse landscape. These ratios and mitigation requirements will be taken into consideration when preparing the master plan and the proposed planting plan for the Campus.

Wetlands

The wetland areas are concentrated around the four ponds on the property which are utilized for their recreational characteristics year-round. The Aspen Country Day School has ice skating during recess and both clients provide canoes to their students in the warmer months. Because all of the ponds on the site are man-made, the supported riparian vegetation is not required to be mitigated if disturbed, however, it is recommended the wetland regions not be disturbed.

Wildlife

The property does lie within outstanding black bear habitat and bears are common, but conflicts are very rare. The main measure to be taken is to provide bear-proof maintenance procedures and site furniture, common in the Aspen area to avoid confrontation with bears. An example being bear-proof trash bins.

In addition the elk migration corridor runs to the north east side of the site crossing the creek. This corridor needs to be maintained. Elk often wander onto the Campus in the fall and winter months, but there are not active elk habitats occurring on the Campus.

conclusions

From the inventory, there are certain overall constraints affecting the development of the Campus. The constraints indicate areas of the Campus that should not receive buildings. The areas include:

- areas of greater than 30% slopes
- areas within the rockfall zones
- areas identified to be severe avalanche hazard
- within the floodplain of the creek
- within the riparian line of the creek
- areas that would obstruct the elk migration patterns

The wetland areas are also not to be disturbed and should be restored wherever possible. Wetlands also provide a strong opportunity for enhancement visually and ecologically. In addition, although building within the steep slopes can be hazardous, building into the slope could provide some protection from potential rockfalls and slope failure in the future due to heavy erosion.

The geologic, hydrologic, wildlife, and political conditions of the site will be combined with acoustic research to move forward into site analysis.

site analysis

The analysis of the Castle Creek Campus is based on the cyclical process of bringing together the proposed program elements, the identification of opportunities and specific constraints related to site context, and site acoustics. The process of analysis begins with conducting a comparative sound study and then applies the results to develop a development program for the Campus (*Fig. 40*).

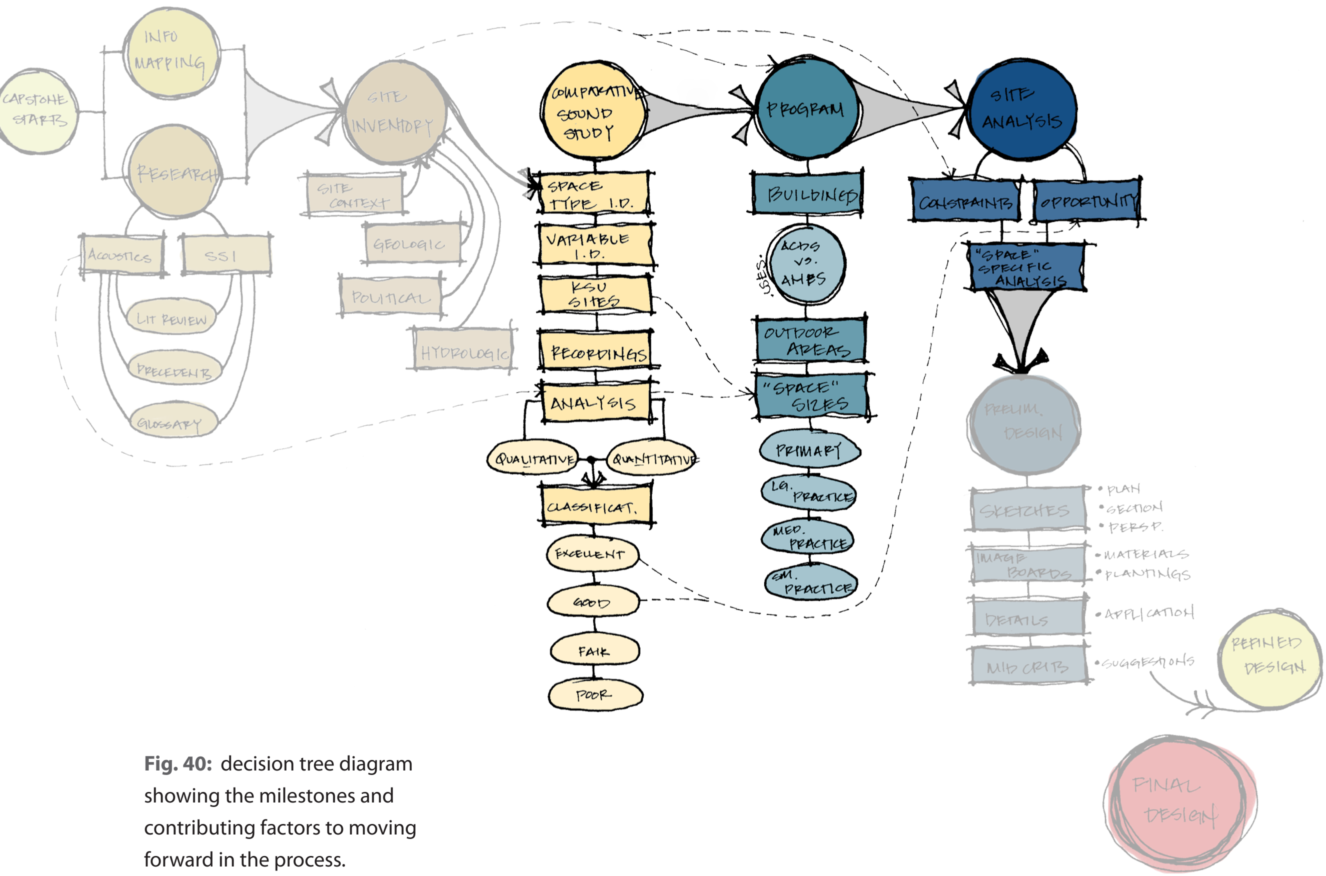


Fig. 40: decision tree diagram showing the milestones and contributing factors to moving forward in the process.

comparative sound study

The comparative sound study presents a method for analyzing the acoustic conditions on the Campus. The study is, physically, conducted on the Kansas State University Campus, then translated to the context of the Castle Creek Campus. Direct study of the Castle Creek Campus was not possible due to time and funding constraints. The purpose of the study was to classify and determine outdoor acoustical quality of specific spaces on the Castle Creek Campus. For the full sound study see Appendix B.

method description

The method for doing such a study began with determining variables which effect sound on the Castle Creek Campus (*Fig. 41*). These variables were chosen based on 4 site visits at various times of the year, personal knowledge of the Campus and aerial/site photos (see site photos on pp. 36-37). These variables were then applied to the KSU Campus to identify sites which would reasonably represent the variables as well as the physical conditions of the Castle Creek Campus. The sites were chosen because of their representation of the variables. Digital recordings of fiddler, Christie Murman were then taken at each site on the KSU Campus using a digital audio recorder. In addition to recording, data sheets were completed for each site to keep record of weather conditions, layout of the space, vegetation in the space, surrounding activities such as construction and materials in the space (*Fig. 42*).

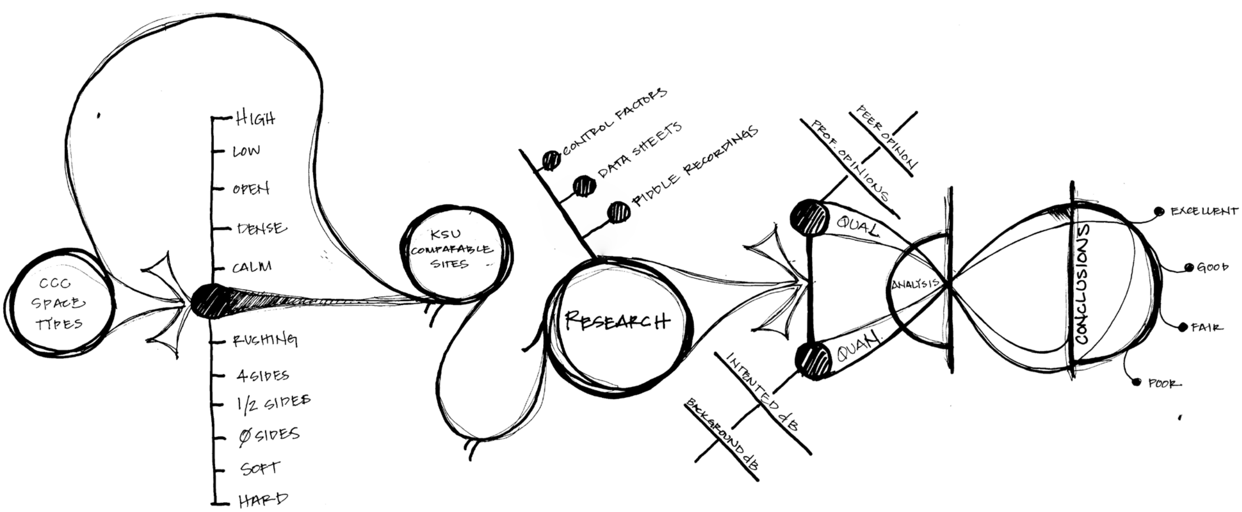


Fig. 41: process diagram of comparative sound study

Site: #2 Bosco - Materials

Weather Conditions: sunny
lt breeze
56°F

Time: 11:42

Date: 10.27.08

Description: turf grass 3' from conc. wall w/ tiered arborvitae evergreen veg.

Vegetation - turf; Eg shrubs
1 small tree

Wildlife - crickets (1)

Materials - conc. limestone

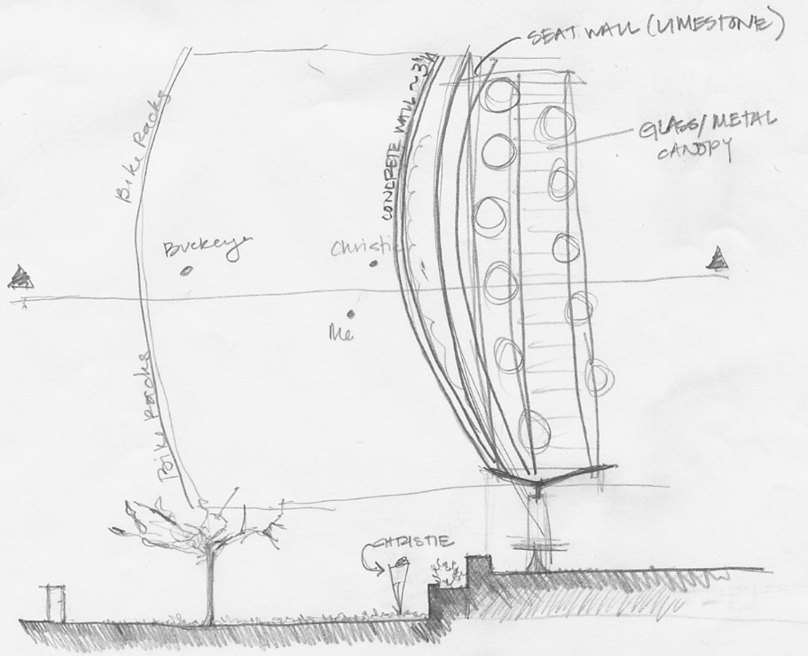


Fig. 42: example of data sheet completed while recording fiddle for each site.

The audio recordings were then analyzed both qualitatively and quantitatively with regard to the extent of background noise interruption and clarity of intended sound (fiddle). Second, the qualitative analysis was done using sound analysis software which graphically showed the effect of background noise and sound clarity. The qualitative analysis involved conducting a survey. Each participant of the survey was electronically sent a form linked to the recordings done on the KSU Campus. They were asked to rate the clarity of the intended sound of the fiddle.

Participants in the survey were selected in three categories; "layman, broadcasting professional and videographer professional." After compiling the results, each variable was classified based on the analysis into a "Excellent," "Good," "Fair," or "Poor" category.

conclusions of comparative sound study

Comparing the resulting classifications of the quantitative and qualitative analyses produced different, but similar results. Many of the classifications were no more than one category off. For instance, in the quantitative analysis Track 6 (Site 3 - "Soft and 0 Sides") was classified as "excellent," but in the qualitative analysis is was considered "good."

The only exception is Track 10 (Site 6 - "4 sides"). It dropped from "excellent" to "fair." It was discovered that this was due to the portion of the recording participants listened to. Before taking the survey, participants were told that they did not need to listen to the entire recording, just a couple of minutes. On this particular track in the first minute there is a particular note Christie plays that causes the recording to get fuzzy. This is likely due to the quality limitations of the recording equipment and not a result of the space's acoustics, but should still be taken into consideration.

The following classifications are based on both qualitative and quantitative analysis.

Classifications

Excellent

- Track 2 Site 1 - "1 to 2 sides"

Good

- Track 3 Site 2 - "materials"
- Track 6 Site 3 - "soft surface and 0 sides"
- Track 7 Site 4 - "high and open canopy"
- Track 9 Site 5 - "dense and low canopy"
- Track 10 Site 6 - "4 sides"

Fair

- Track 5 Site 2 - "hard surface and 0 sides"
- Track 8 Site 5 - "low canopy"

Poor

- Track 4 Site 2 - "rushing water"

From the classifications it is apparent that certain conditions are more suited to musical propagation than others. Creating a mounded form within a space creates the best quality of acoustics due to the "excellent" rating the category received. This will be taken into consideration when locating the practice spaces on the Campus.

When selecting materials, the study shows that primarily soft surfaces allow for the greatest sound absorption coefficient and therefore result in a better quality of acoustics than hard surfaces (however, note that the difference is slight, making hard surfaces appropriate as well).

In addition, surrounding the space in "low and dense" canopy trees appears to heighten the acoustic quality as apposed to open air conditions. This is consistent with Beranek (*see p. 22*).

All of these findings will play a large role in the placement and site specific design of the performance and practice spaces on the Castle Creek Campus.

programming

The program for the Castle Creek Campus is based on that which was proposed collectively by the clients, architects (Harry Teague Architects) and landscape architects (Design Workshop Inc.). However, this program has been strategically reduced in order to implement more sustainable practices. There are three types of programming addressed; "space" sizes, buildings, and outdoor spaces.

The previously desired program called for approximately 15 percent more development than what the site could hold due to the hazardous constraints outlined in the inventory. The building footprints were strategically reduced while meeting the most necessary demands.

In addition, the square footage and possible layout of the performance and practice spaces were determined.

"space" sizes

The performance and practice spaces are sized based on the number of users (*Fig. 43, 44*). These sizes represent the minimum square feet that the performance and practice spaces can be, while still meeting client requirements.

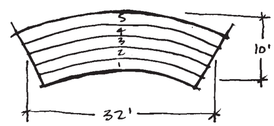
SPACE SIZES:

PRIMARY PERFORMANCE SPACE

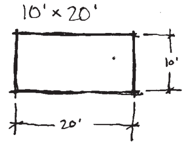
Seating capacity: 100-150 people.
Square feet per person: 4'2

8'x40' .... 4 rows x 40' long
*10'x32' .... 5 rows x 32' long
16'x20' .... 8 rows x 20' long
106 ppl.

*1 row = 24' deep



Stage size: 10-25 ppl.
10'x20'



SEATING CAPACITY*

LENGTH (FT)

ROW	8	12	16	20	24	28	32	36	40
3	16	24	32	40	48	56	64	72	80
4	21	32	42	53	64	74	85	96	106
5	26	40	53	66	80	93	106	120	133
6	32	48	64	80	96	112	128	144	160
7	37	56	74	93	112	130	149	168	186
8	42	64	85	106	128	149	170	192	213
9	48	72	96	120	144	168	192	216	240
10	53	80	106	133	160	186	213	240	266
12	64	96	128	160	192	224	256	288	320
14	74	112	149	186	224	261	298	336	373
16	85	128	170	213	256	298	341	384	426
18	96	144	192	240	288	336	384	432	480
20	106	160	213	266	320	373	426	480	533

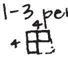
*Consult manufacturers for additional information.

Fig. 43: primary performance space sizing based on a seating capacity of 100 to 150 people.
Source: Hopper 2007 p.880

SMALL PRACTICE SPACES:

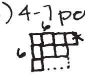
• 3 different sizes:

(5) 1-3 person



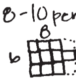
4'x4'

(3) 4-7 person



6'x6'

(2) 8-10 person



8'x6'

Fig. 44: minimum practice space sizing requirements broken into three different sizes; small, medium and large.

BUILDINGS	EXISTING TO REMAIN	NEW	USE
ADMINISTRATION BUILDING	5,351 s.f.	Ø	• Year-round offices • Central Reception Area
BUSINESS BUILDING	2,268 s.f.	Ø	• Year-round offices • Archive space
CAFETERIA	Ø	4,000 sf.	• includes kitchen • activity area • equipment storage area
CASTLE CREEK BUILDING	10,036 sf.	3,600 s.f.	• New student center • Large chamber Music Rehearsal
CHAMBER MUSIC HALL	Ø	4,800 sf.	• Large & small rehearsal spaces.
CLASSROOM BUILDING	Ø	1,500 s.f.	• classes and rehearsal spaces
LARGE ENSEMBLE SPACES	Ø	4,100 s.f.	• rehearsal spaces • classroom space
MAINTENANCE BUILDING	Ø	3,400 sf.	
MUSIC HALL	Ø	3,600 sf.	• largest rehearsal space
OPERA HALL	Ø	2,402 sf	• large rehearsal space • teaching studios
PRACTICE ROOMS	Ø	6,725 s.f.	• Practice spaces in summer • storage in winter
PERCUSSION BUILDING	Ø	1,300 sf.	• practice space in summer • storage in winter
TOTAL	17,655 sf.	35,421 sf.	

Table 2: building names, sizes and uses reduced from previous program.

OUTDOOR SPACES	EXISTING TO REMAIN	NEW	LOCATION
LOWER ELEMENTARY PLAYGROUND	3,200 sf.	ϕ	New elementary building (classroom building)
KINDERGARTEN FENCED PLAYGROUND	ϕ	1,500 sf.	Chamber Music Rehearsal
UPPER ELEMENTARY PLAYGROUND	4,400 sf.		Castle Creek Building
PLAYING FIELD	ϕ	5,000 sf.	Unknown at this time
OUTDOOR CLASSROOM	ϕ	800 s.f.	Unknown at this time.
LAWN FOR GRADUATION / PRIMARY OUTDOOR PERFORMANCE SPACE	ϕ	520 sf	Unknow at this time.
SMALL PRACTICE SPACES	ϕ	284 sf	Unknown at this time.
PARKING SPACES (90 stalls)	ϕ	17,500 sf.	Unknown at this time.
BUS TURNAROUND	6,000 s.f.	2,000 sf.	Middle Bridge Area
ICE SKATING / BOATING POND	30,000 sf.	ϕ	Great Pond
TOTAL	43,600 s.f.	27,604 sf.	

Table 3: outdoor space names, sizes and uses reduced from previous program.

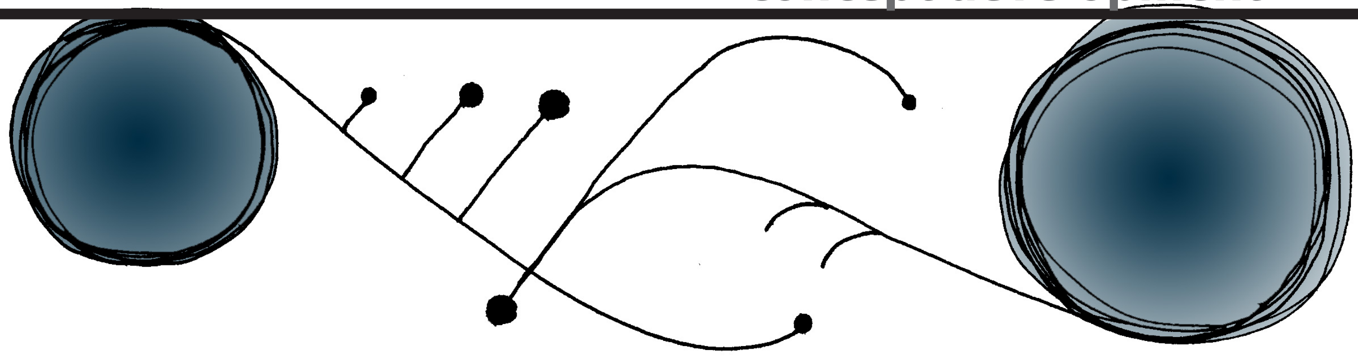
inventory and analysis conclusions

Completing inventory and analysis for the site conditions and acoustic conditions provided the basis for the program which includes one primary performance space and three different sizes of practice spaces. Specifically, in order to achieve quality acoustics it is necessary to identify variables affecting the acoustics of the identified spaces. Variables include:

- organization of the space
- materials within the space
- proximity to water
- vegetation choices
- degree of enclosure

Through concept development, the next step in the design process, is to place the performance and practice spaces on the Castle Creek Campus, taking into consideration the delicate site conditions and resulting classification of variables made through the comparative sound study.

concept development



introduction

Developing a concept for the campus involved bringing together the findings of site analysis, comparative sound study and research. Within the design there are two primary realms of understanding applied, acoustics and sustainability. Each realm plays a significant role in the design. Both were used in the placement of the performance and practice spaces. Acoustics plays a stronger role in the more detailed design relating to material selection. The concept meets the remaining objectives established in the introduction (p. 7-8) that have not been met in research, site inventory or analysis.

objectives

Goal 1 - Bring small performance venues outdoors without losing acoustic quality.

- Objective 1-5: Create a multifunctional gathering space for both clients.

Goal 2 - Increase student enrollment

- Objective 1: update aging facilities or completely demolish and rebuild where necessary.
- Objective 2: make the campus unique in comparison to other musical institutions through innovative site design and outdoor acoustic quality.

Goal 3 - Incorporate SSI guidelines into the placement and design of spaces and the campus in general.

- Objective 1: preserve the natural character of the site and rustic character of the architecture.
- Objective 3: alleviate development pressure on the site by strategically reducing program requirements (in terms of building square footage).
- Objective 4: use native vegetation, requiring less irrigation.
- Objective 7: reuse existing structures/materials and order new materials from local dealers for all new development.

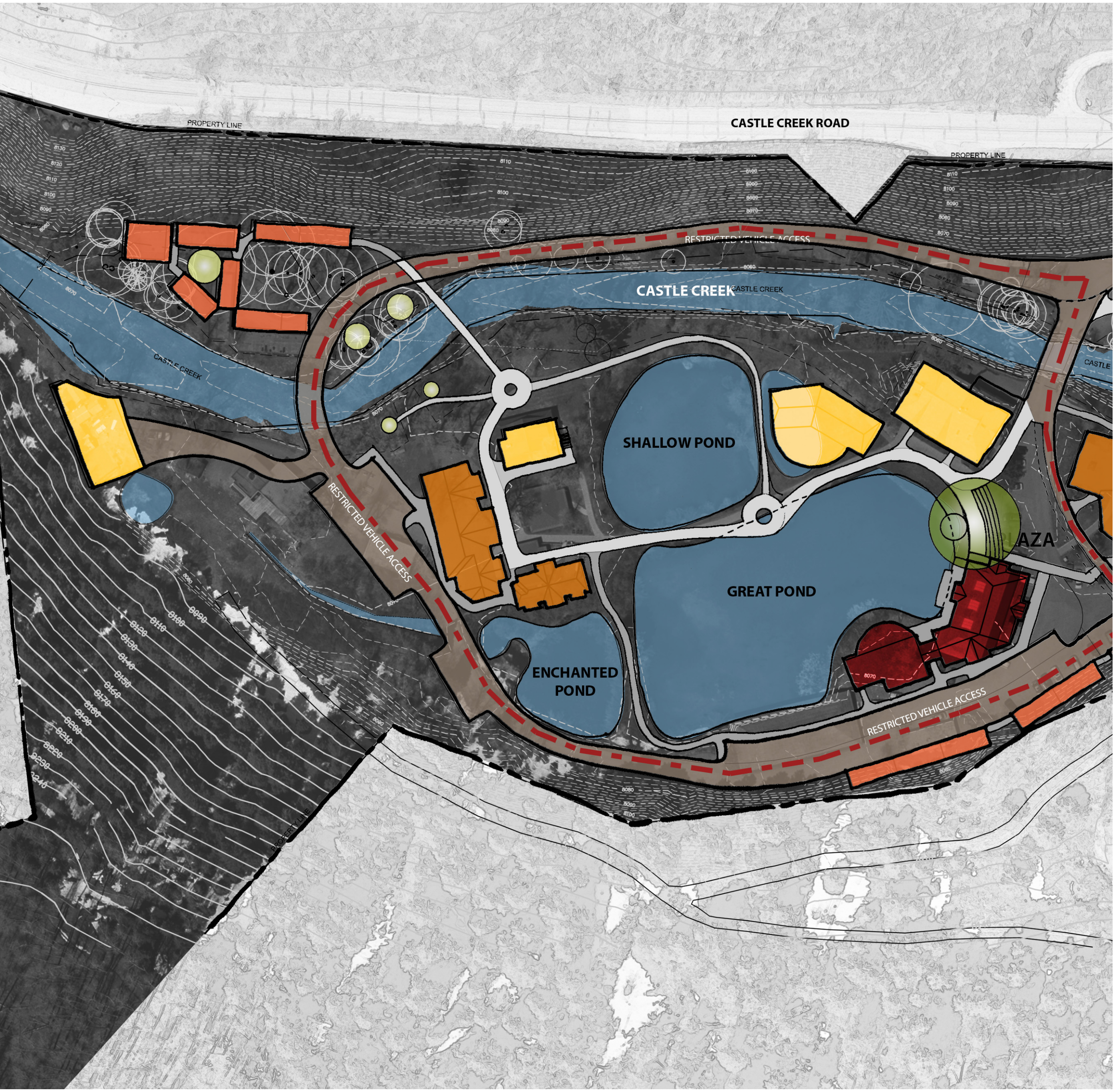
concept statement

The design of the Castle Creek Campus focuses on making connections between students and faculty, the natural and structural, the artistic (acoustically and form) and practical, as well as unmistakable and subtle. These connections are made through multiple layers from the overall organization of the campus to the selection of materials and vegetation. The design enhances the existing character of the campus in a way that meets programmatic needs while establishing quality outdoor acoustics that do not negatively impact the sensitive environmental conditions of the site.

Fig. 45: concept parti of the campus showing the connections of public spaces, performance spaces, and practice spaces as well as major active buildings.

framework plan

The performance and practice spaces are located on the campus according to the findings of the comparative sound study (*Fig. 45*). The placement of these spaces assures the best possible acoustic conditions, before development, for the users. The spaces are located within site conditions found to be "excellent," "good," or "fair" depending on the use of the space. The framework helps to unify the campus in a way that brings students and faculty together through interaction between buildings. Establishing districts based on building use helps to determine where people will be moving through the site and where they are most likely to gather. Shown on Figure 46, there are 4 district types; classroom, administration, practice buildings and performance buildings.


CASTLE CREEK ROAD
PROPERTY LINE
PROPERTY LINE
RESTRICTED VEHICLE ACCESS
CASTLE CREEK
CASTLE CREEK
CASTLE CREEK
CASTLE
SHALLOW POND
GREAT POND
ENCHANTED POND
AZA
RESTRICTED VEHICLE ACCESS
RESTRICTED VEHICLE ACCESS

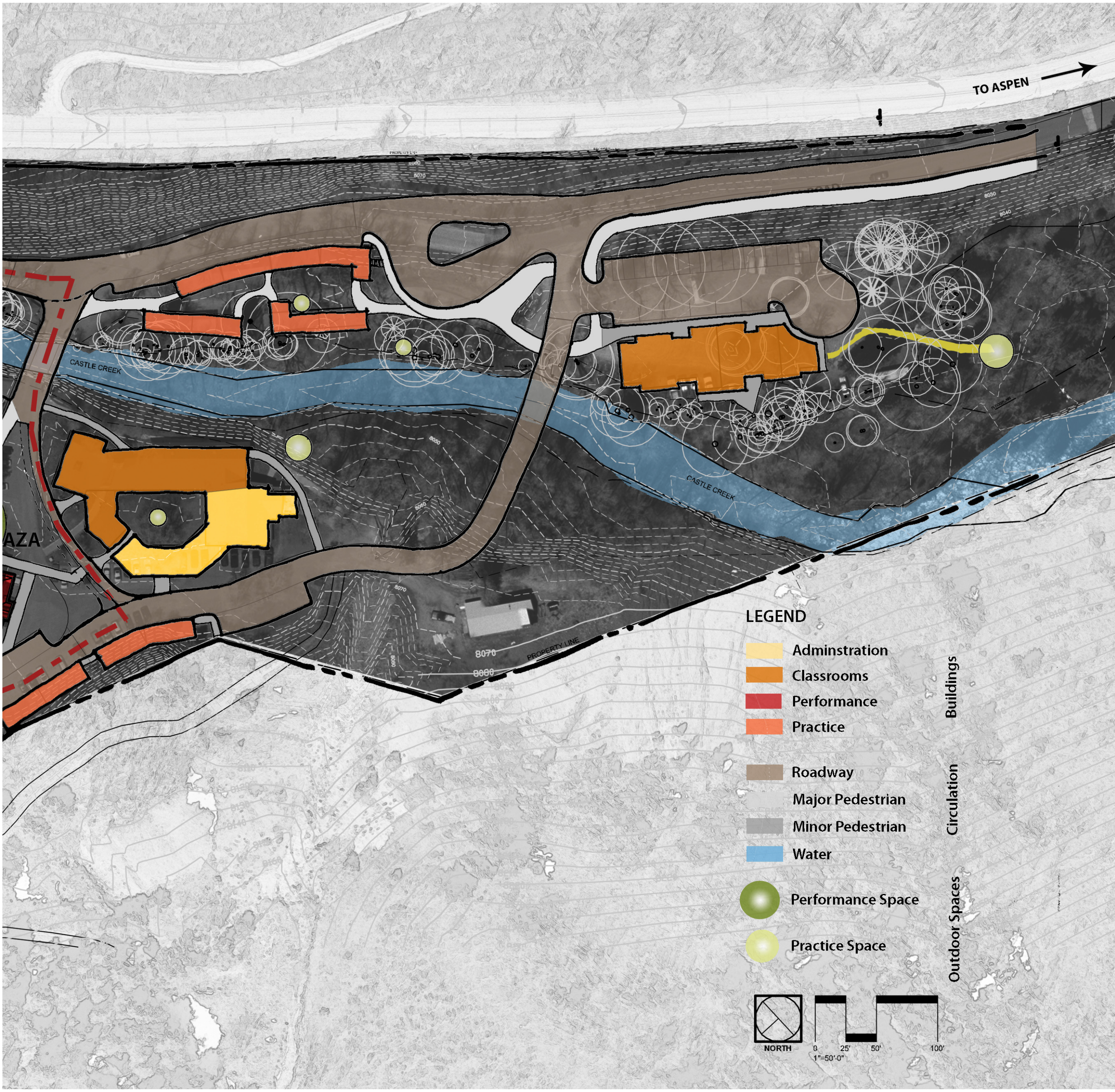


Fig. 46: framework plan displaying the districts, circulation patterns, and performance and practice space locations on the Castle Creek Campus

Vehicular, major pedestrian and minor pedestrian circulation patterns are shown as well. It is important to note that all vehicular circulation routes can, and likely will be used for pedestrians due to the low volume of cars coming into the campus. On a daily basis, there is not any significant car traffic except when school begins and ends due to parent picking up their children. It is recommended that the owners utilize satellite parking with shuttles to and from the campus when events with high volumes are likely. Doing so allows for fewer parking lots, maximizing developable area on the site.

The circulation of the vehicular traffic moves in a circular pattern around the campus, but much of the roadway is blocked to visitors and parents, serving only maintenance, delivery, and teacher access needs. The restricted area begins just after the middle bridge and ends at the the Castle Creek Campus Building (*see Fig. 46*).

concept plans and models

In order to work through development of the concept it was necessary to quickly and schematically design the four space types (performance, large, medium and small practice spaces) to explore what possibilities existed. Clay models were built to understand the spatial relationships of the extensive landform and buildings to the "negative" space that would become the performance and practice spaces.

The model of the overall campus shows the steep valley setting. The lack of developable area is evident in the representation (*Fig. 47*) . For the performance space, the exploration of the stage located within the water is shown. In addition, the close proximity of the existing administration building and proposed music hall is apparent (*Fig. 48*). The large practice space is completely surrounded by one story practice rooms and very large trees close to the creek (*Fig. 49*). The medium practice space is nestled in one of the higher quality riparian areas creating a more intimate. less public feel (*Fig. 50*). The small practice space is located in close proximity to practice buildings which can be made to feel either intimate and secluded or more "showcase" oriented (*Fig. 51*).

Fig. 47: photo of clay model representing the proposed overall campus conditions.

Understanding the spatial relationships for each space size led to the exploration of site specific design concepts which incorporate the unique conditions surrounding the spaces.

Fig. 48: photo of clay model representing the proposed performance space.

Fig. 49: photo of clay model representing the proposed large practice space.

Fig. 50: photo of clay model representing the proposed medium-size practice space.

Fig. 51: photo of clay model representing the proposed small practice space.

key design elements

introduction

The final design for the Castle Creek Campus focuses on the four outdoor "space" sizes which include a primary performance space and large, medium and small practice spaces. The design of these spaces is the culmination of the understanding gained through in-depth literature research, inventory of existing site conditions, comparative sound study, establishment of a program and finally the application of that program in the form of a framework plan. Through concept development specific connections became important to creating a unified campus. The connection between students and faculty, the natural and structural, the artistic (acoustics and form) and practical and unmistakable and subtle provide the basis for detailed design. Creating these connections is the measure of success for the design of the four space sizes.

As the concept statement (*p. 59*) states "The design enhances the existing character of the campus in a way that meets programmatic needs while establishing quality outdoor acoustics that do not negatively impact the sensitive environmental conditions of the site." This applies to the detailed space design as well as to the larger scale Campus design.

acoustics

The first of the two major realms of knowledge to be addressed through the design of the spaces is acoustics. Since the initial project definition, acoustics has been the inspiration, striving to achieve quality acoustics in the natural environment. Each space applies acoustic principles described on p. 21 while expressing the connections between users, nature, art, and perception. In order to achieve quality acoustics it is necessary to identify variables affecting the acoustics. The variables have been selected due to their importance throughout the research and comparative sound study. Variables include:

- organization - the organization of the spaces affects the interaction of its users as well as their perception of the space. In addition, the organization can profoundly alter the acoustic projection of music as described in the literature research on p. 23.
- materials - the materials chosen for enclosures and surfaces can influence acoustics through the alteration of reverberation time and sustainability through the re-use of existing materials already on-site or in the surrounding area.
- proximity to water - acoustically, it was discovered that rushing water (like that of Castle Creek) reduces sound quality and that calm water (the ponds) can enhance acoustic quality. Sustainably, it is preferred, and in some cases required, to keep the more "built" spaces such as the performance and large practice spaces away from the creek.
- vegetation - using native vegetation is highly desirable. Acoustically, much of the native vegetation is dense providing sound absorption for music. Sustainably, rejuvenating the disturbed areas with their native flora creates a more stable micro-environment over the long term.
- degree of enclosure - the benefits of providing enclosed spaces is more apparent in acoustic terms than in environmental. However, on this already cramped site, placing buildings closer together decreases the development footprint while creating reverberant spaces.

Each of the above variables are identified and described for the four space sizes.

Source for inspirational images: www.flickr.com 2009

performance space

The performance space is designed to be "unmistakable," a landmark piece for the Castle Creek Campus. One aspect of its uniqueness is not only the artistic expression of form, but the practicality of the acoustic considerations in its design. It is designed to hold between 100 to 150 people.

organization

The performance space is organized in a fan shape, which through research, was determined to be the most appropriate organization for outdoor venues. In addition, the direction of the audience allows for picturesque views to be seen of the mountainside. This view is also important in the material selection.

materials

From the sound study it was determined that having a mixture of soft and hard surfaces is desirable for quality acoustics. The performance space focuses on utilizing "hard" materials due to the heavy use of the space, but incorporating the lawn area behind the audience allows for some absorption of sound before it can reflect off of buildings back to the audience. In addition, the use of a metal fabric (see appendix c) directs the sound out of the band shell while still allowing the view of the mountainside.

proximity to water

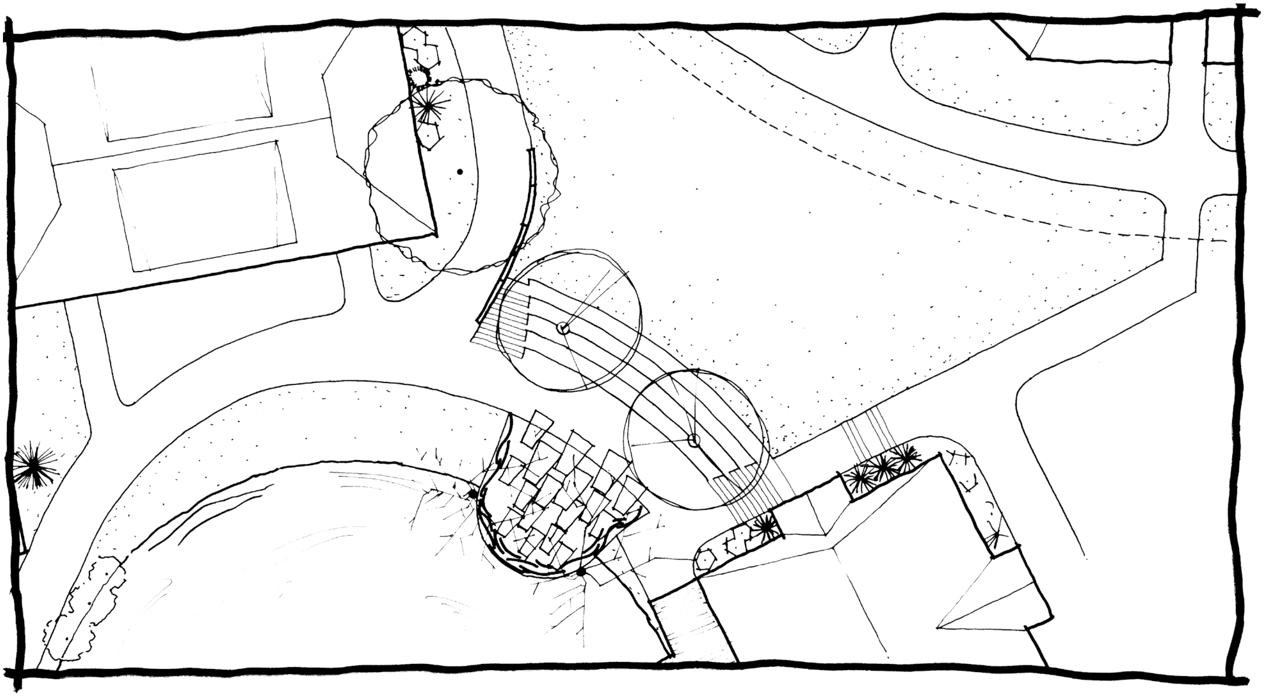
The performance space is not within hearing distance of the rushing creek, so it is not a major concern. The Great Pond is very still, very little movement in the water unless activities are occurring.

vegetation

To help decrease reflected sound some high canopy trees have been placed within the performance space. Other than these, the vegetation is kept to a minimum to enhance the more structural feeling of the space.

degree of enclosure

The placement of the performance space is meant to keep the space open and unenclosed. The space does not contain obstructions between the stage and the audience allowing the music to easily move through the air.



pavement

water

buildings

vegetation (open/dense)

enclosure (open/ mounded form/ fully enclosed)

Fig. 52: acoustic variables shown in plan

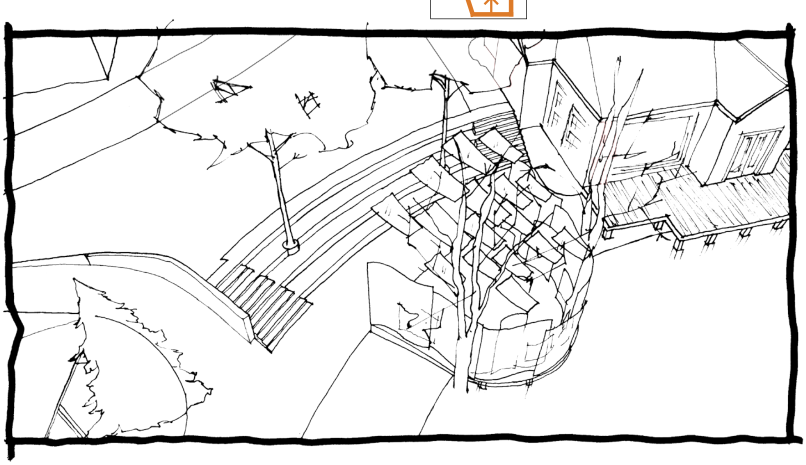


Fig. 53: acoustic variables shown in perspective

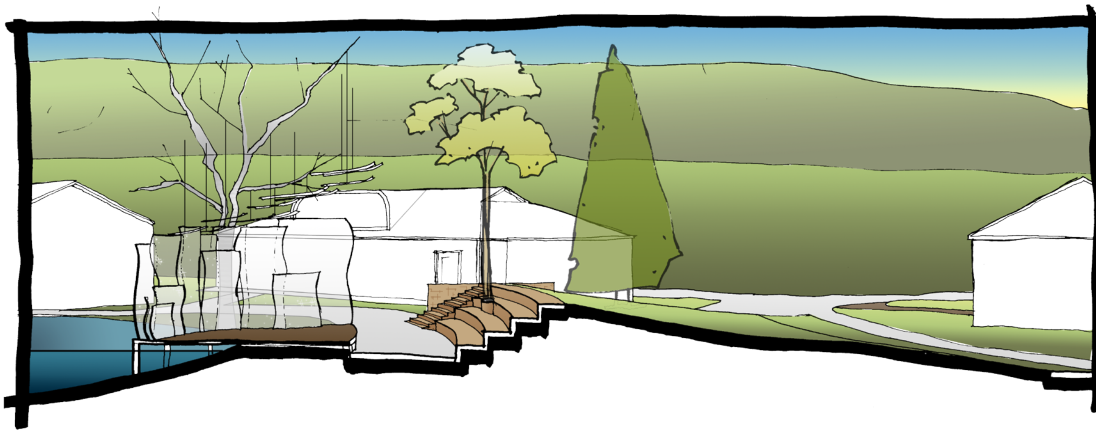


Fig. 54: section of the performance space showing the landform and relationship of the audience to the stage area and bandshell. The "tree" sculpture supporting the overhead panels will be made of metal, but woven, made to look like thousands of metal twigs intertwined.

Fig. 55: perspective of the space displaying the gentle slope of the lawn area for overflow and some reflection reduction purposes.

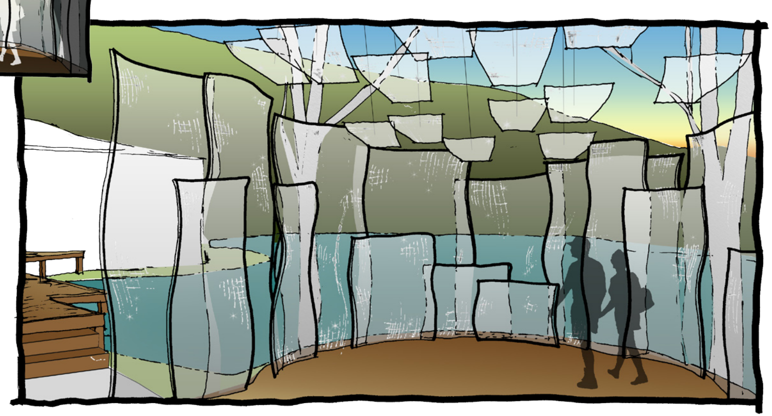


Fig. 56: view towards the mountainside, through the 50% transparent metal fabric. (vignette night shot above)

large practice space

The large practice space is slightly less structural than the performance space; it is semi-formal. The space has three main uses: practice for about 10 students, small performance for 15-20 people, and showcase for a small group of students. By showcase, I mean that the students are playing to show off their skills for other students and faculty in a less formal manner then a "performance."

organization

The organization allows for the flexibility of use that is required. Placing small permanent seating structures allows for a number of seating possibilities. Students practicing can sit in a circle on the columns, or an audience can gather and direct their attention to the bench at the northern edge.

materials

Again, the large practice space has a mixture of materials to accomplish the most desirable reflective and absorption ratio. The ground plane is approximately 75% hard. In addition, the materials used include native sandstone as well as the metal fabric as a screen to reflect sound from the bench area toward the pedestals.

proximity to water

This space is particularly close to the creek, but can be shielded from the "noise" created by the creek through dense vegetation.

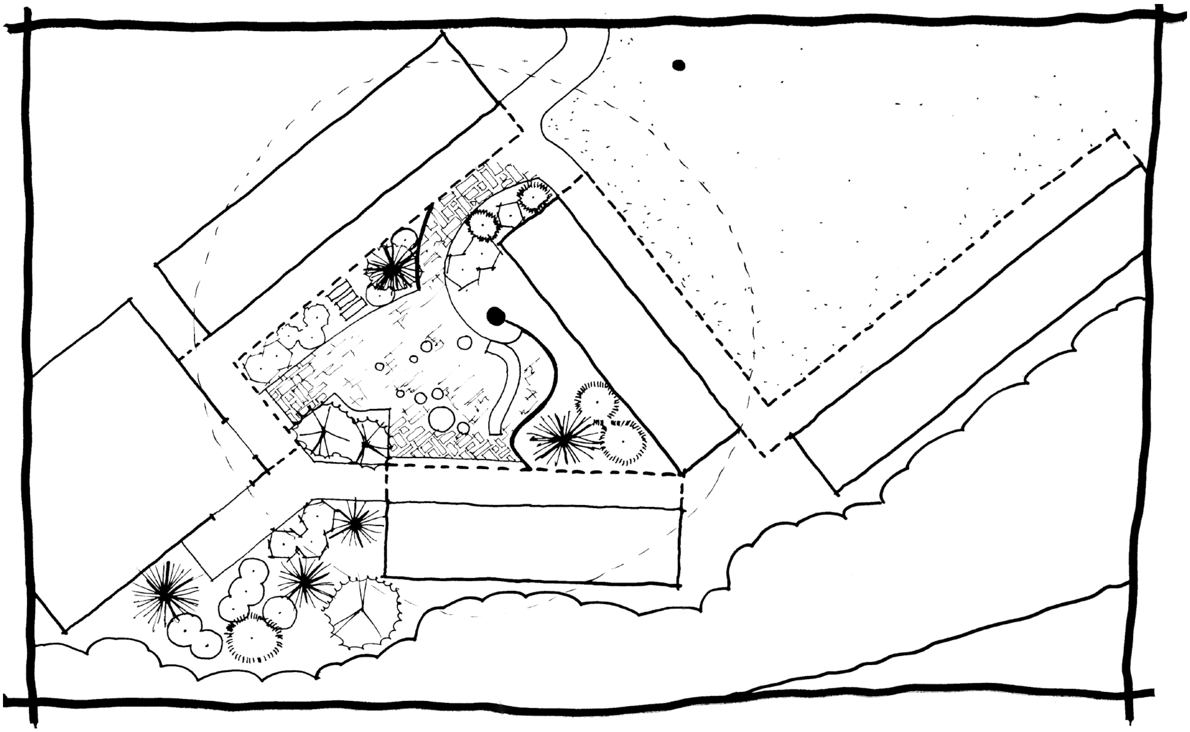
vegetation

The vegetation begins to play more of an absorption role here because the music does not need to carry as far from the sound source. The sound study tells us that providing low, dense vegetation is more appropriate for small musical gatherings.

degree of enclosure

The degree of enclosure of this space is relatively high. Similar to the courtyard used in the sound study, this space will have some reverberation from the surrounding buildings. In addition, the high canopy of surrounding trees gives a ceiling for the space to keep some of the sound within the space.

Source for inspirational images: www.flickr.com 2009



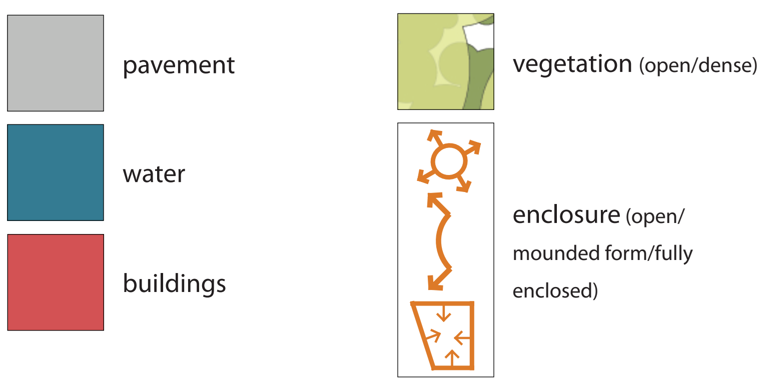


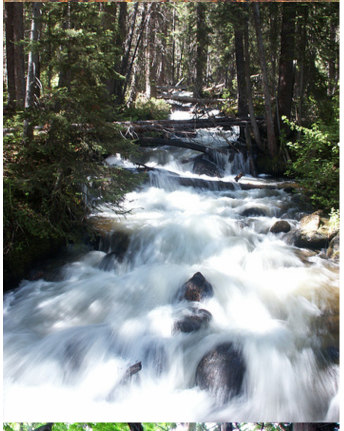
Fig. 57: acoustic variables shown in plan

Fig. 58: acoustic variables shown in perspective

Fig. 59: section of the large practice space. The reflective qualities of the space are shown in the arrows.

Fig. 60: perspective of the space displaying the sense of arrival as you come upon the space due to the location of the metal fabric screen.

Fig. 61: view toward the more structured formal seating area at night.

Source for inspirational images: www.flickr.com 2009

medium practice space

The medium practice space is considered to be semi-informal. It is identifiable, yet hidden. The hidden nature of the space creates a sense of discovery. One can only find it if they know where it is or if they are told where to look. The space is designed to accommodate four to seven musicians for the purpose of practicing their craft.

materials

Here, the materials used are more natural. The ground plane is softer than the large performance space. The path leading down to the space is comprised of grasses with a sandstone edge. The large boulders act as a retaining wall for the space. Acoustically, the boulders also provide lesser amounts of sound reflection for the musicians. Because there are fewer people, there is less of a need for reflection, focusing more on reverberation. However, the metal fabric is incorporated into the handrail leading to the space as a way to signify “something is down there.”

proximity to water

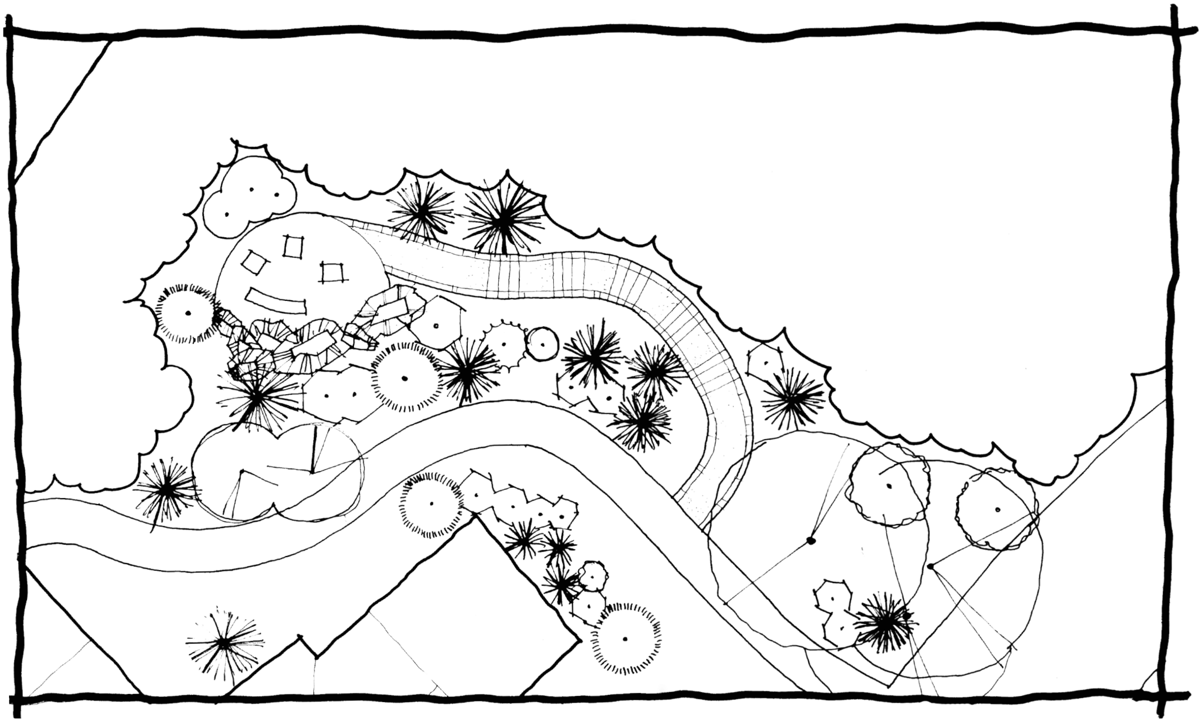
The medium practice space is also placed relatively close to the creek, but the amount of very dense riparian vegetation buffers much of the rushing creek sound. The creek cannot be heard from the space.

vegetation

The dense vegetation follows the results of the sound study, working to absorb the sound from the instruments. Here, the use of vegetation is relied upon for acoustic quality more than structural elements like the metal screen in the large performance space and the large practice spaces.

degree of enclosure

Due to the dense vegetation, and large boulder retaining wall, the space feels very enclosed. It follows the classification of “2-sided” (see appendix b) in the sound study because it is a mounded landform which helps keep sound from escaping the space and directs it back towards the students.



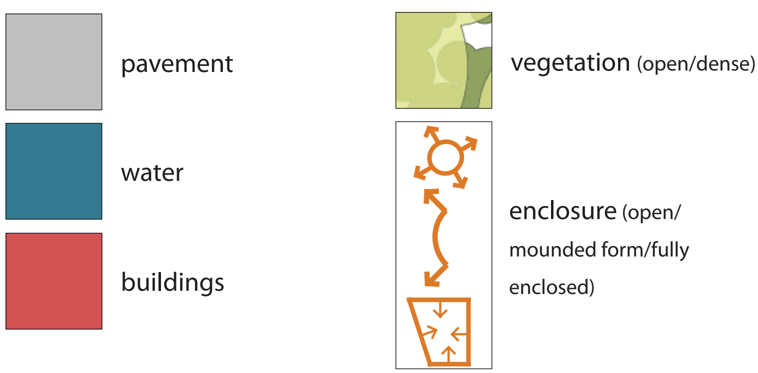


Fig. 62: acoustic variables shown in plan

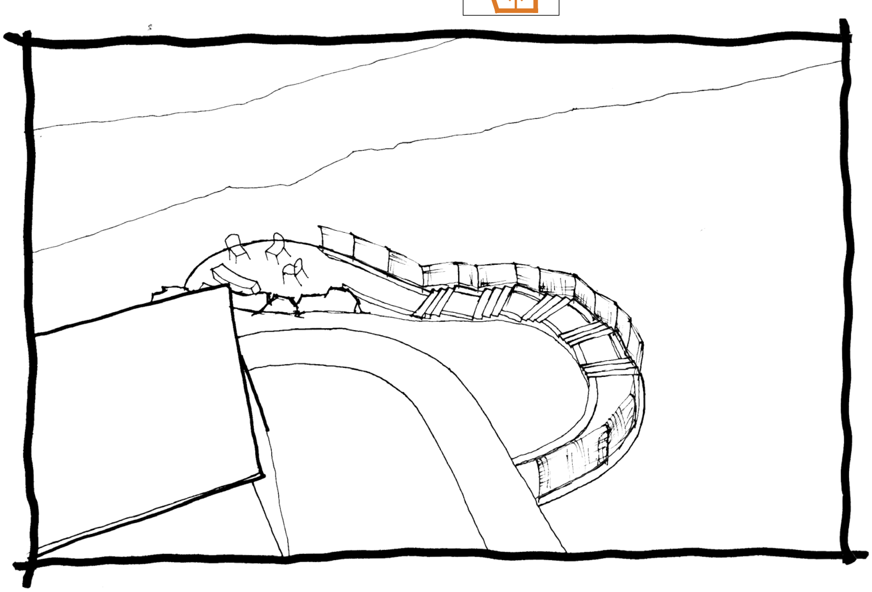


Fig. 63: acoustic variables shown in perspective

Fig. 64: section of the performance space showing the landform and relationship of the audience to the stage area and bandshell.

Fig. 65: perspective displaying the amount of dense vegetation contributing to the sense of enclosure and intimacy.

Fig. 66: view towards the mountainside, through the 50% transparent metal fabric.

small practice space

The small practice space is defined as very informal. Someone walking past wouldn't notice it was there unless they knew where to look. Much like the medium practice space, it is meant to be discovered, to add a sense of mystery and wonder to the campus experience. The purpose is to simply provide a small open area where one to three people can practice their instruments.

materials

In the small space, the materials focus on incorporating what is already existing on the site. The ground plane is nearly entirely soft and large boulders are used for seating. Additional seating can be added by bringing moveable chairs.

proximity to water

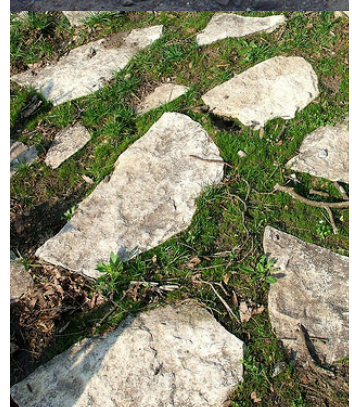
Many of the small practice spaces are in close proximity to the creek, but again, the sound of the rushing creek is blocked by the dense riparian vegetation.

vegetation

Only dense vegetation is used to create the absorption needed. The low dense vegetation, while absorbing sound, reflects just enough that the musician can hear themselves playing.

degree of enclosure

The small practice spaces are very intimate. They are nearly fully enclosed by dense vegetation. The scale of the enclosure is appropriate for the number of expected users as well as adding to the "discovery" aspect of the design.



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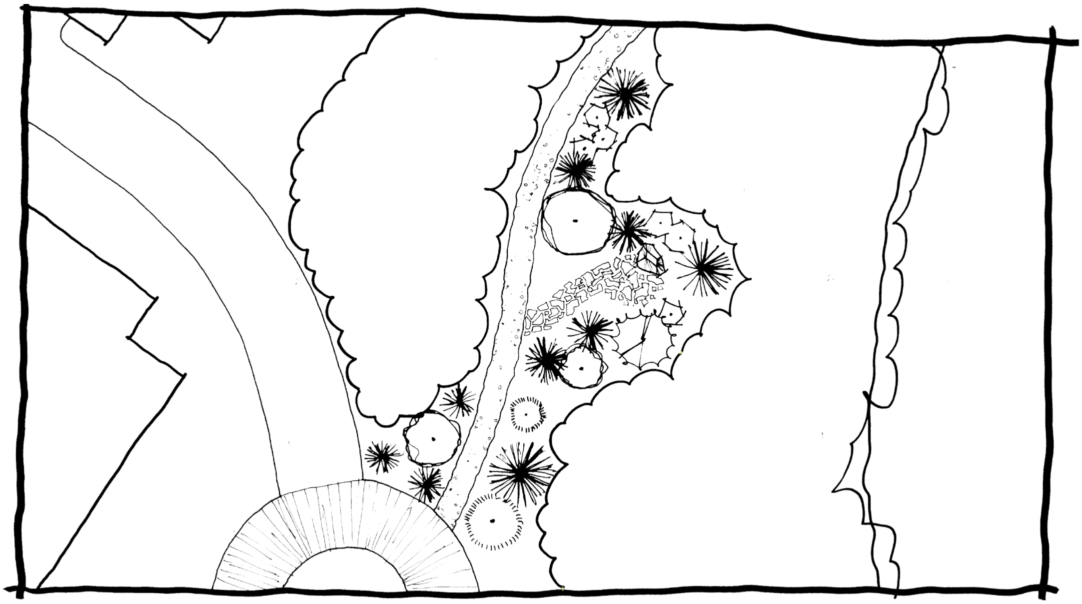
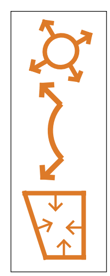


pavement

water

buildings

vegetation (open/dense)



enclosure (open/ mounded form/fully enclosed)

Fig. 67: acoustic variables shown in plan

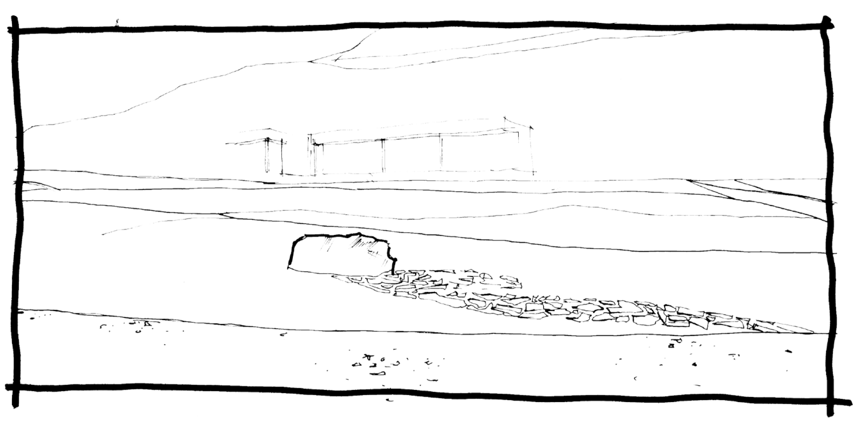


Fig. 68: acoustic variables shown in perspective

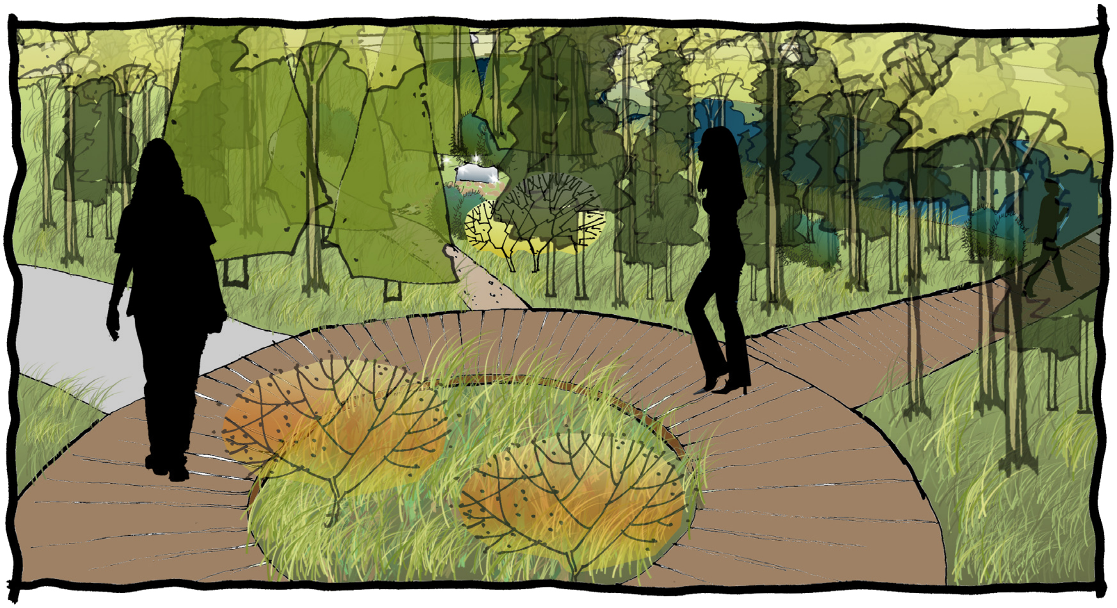


Fig. 69: the small practice space is nearly invisible amongst the dense riparian vegetation. However, the boulder overlaid with the metal fabric announces that there is more to the natural setting.

conclusions

Acoustically, the large practice space utilizes many of the standards and principles known to result in "good" acoustics. The organization, selection of materials, proximity to water, vegetation selection, and degree of enclosure all are designed to enhance the acoustic clarity of the musical performances. The large, medium and small practice spaces focus on using the results of the sound study (see appendix b) to determine the design because of the more intimate use of the space. They don't focus on projecting sound so much as to keep sound close.

sustainability

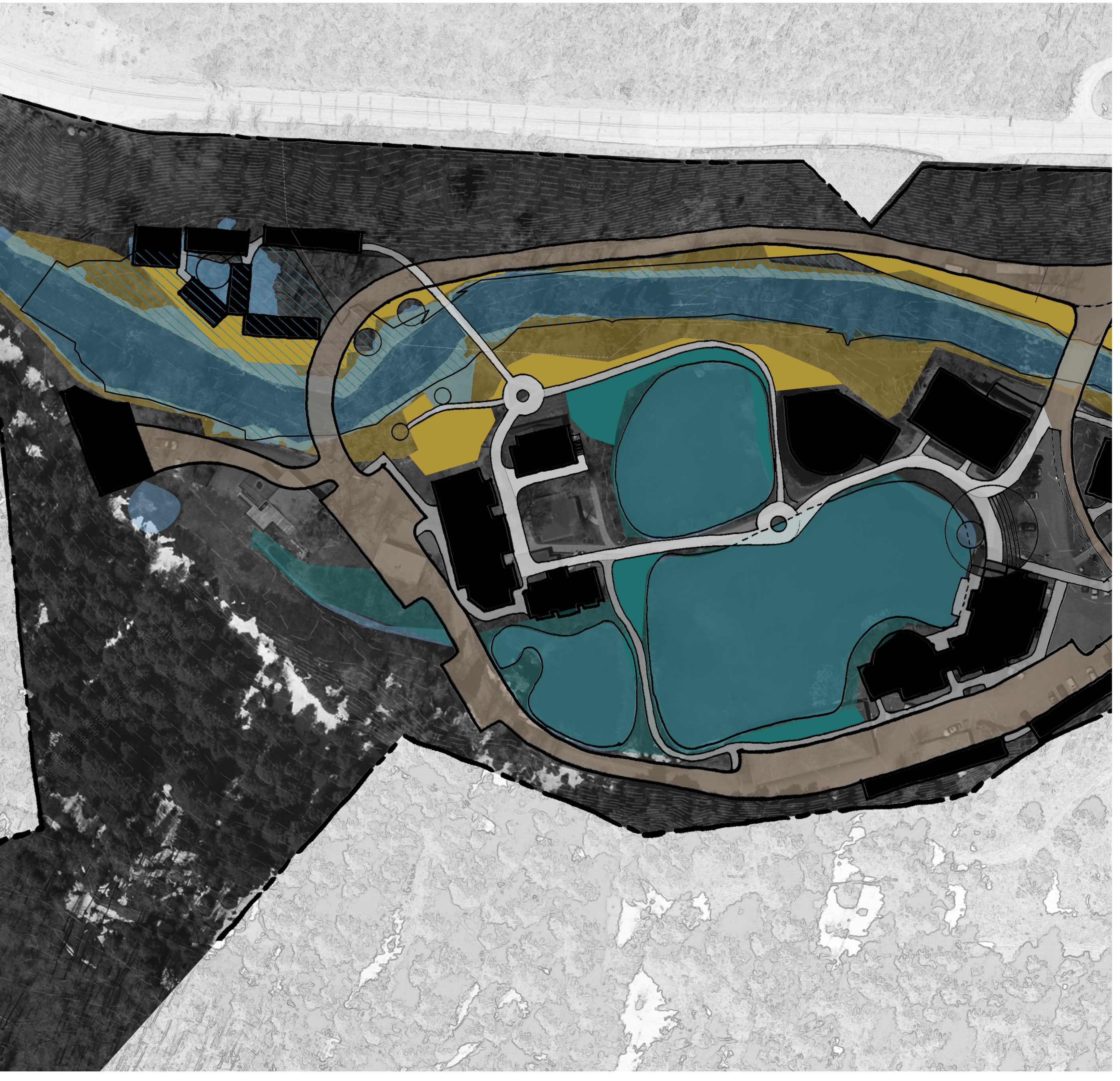
In the development of the framework plan Sustainable Sites Initiatives and LEED (Leadership in Energy and Environmental Design) guidelines were important in making design decisions, as they were in detailed design.

preservation of character and systems on the site

As stated in the introduction and inventory, the existing character of the campus is at the heart of its values. Through the large scale design, the natural beauty of the campus is preserved and enhanced through the restoration and protection of riparian and wetland areas (*Fig. 71*).

At the campus-wide scale, buildings were placed in areas determined to be developable (*see Fig. 72*). These areas did not contain hazardous conditions. The only exception would be the practice rooms which (as recommended by Harry Teague Architects) act as retaining walls holding back some 30% slopes. The building character is preserved in the new design. It is critical that the new buildings project the same aesthetic as the old for the campus to feel unified (*Fig. 73*).

In addition, much of the plant selection is native to the region. The vegetation is chosen based on location within the site responding to multiple ecosystems (*see appendix c*). For instance, parts of the site are classified as uplands which require more drought tolerant plants, whereas other areas are riparian, requiring plants that can handle very moist soils.



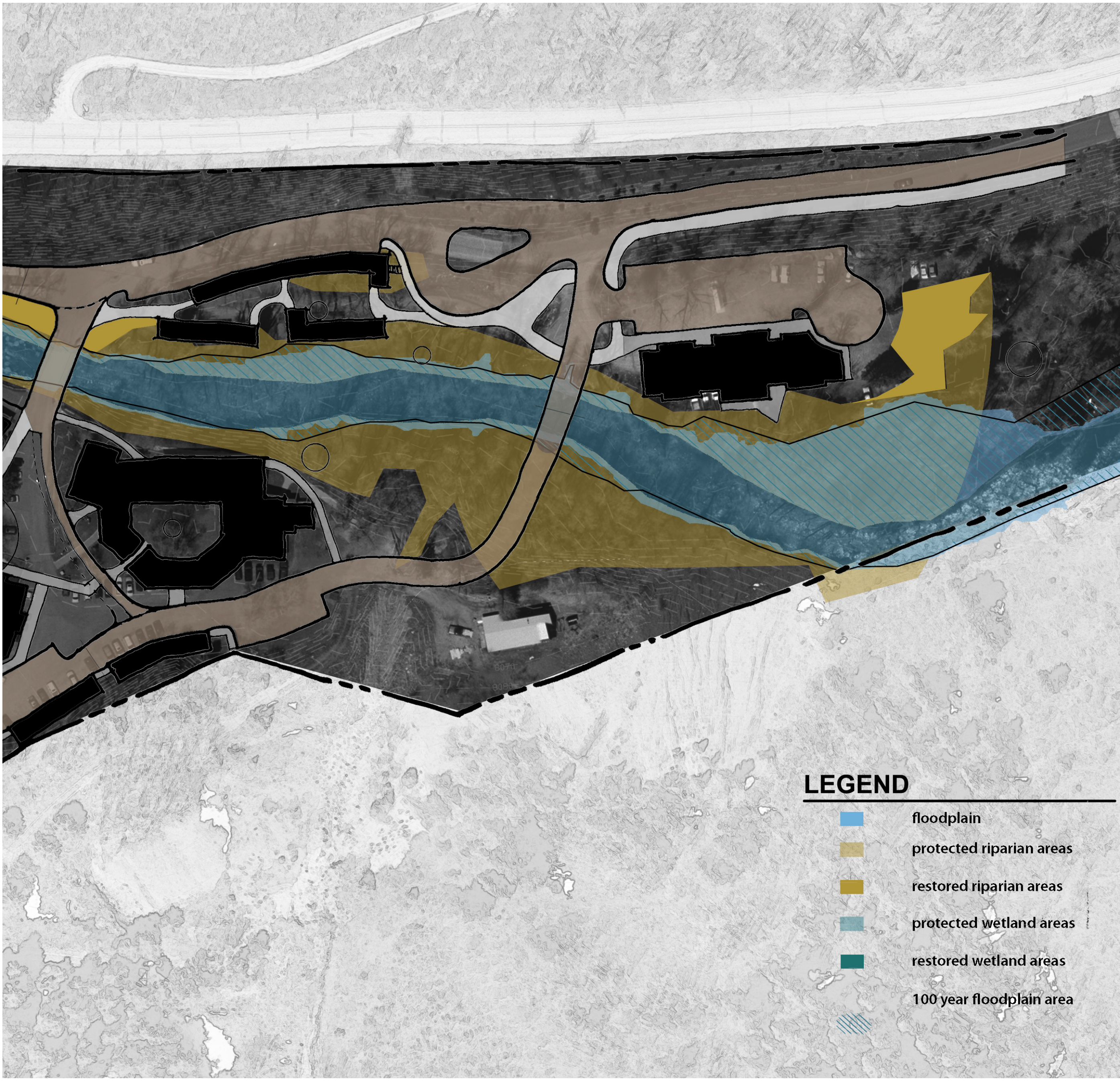
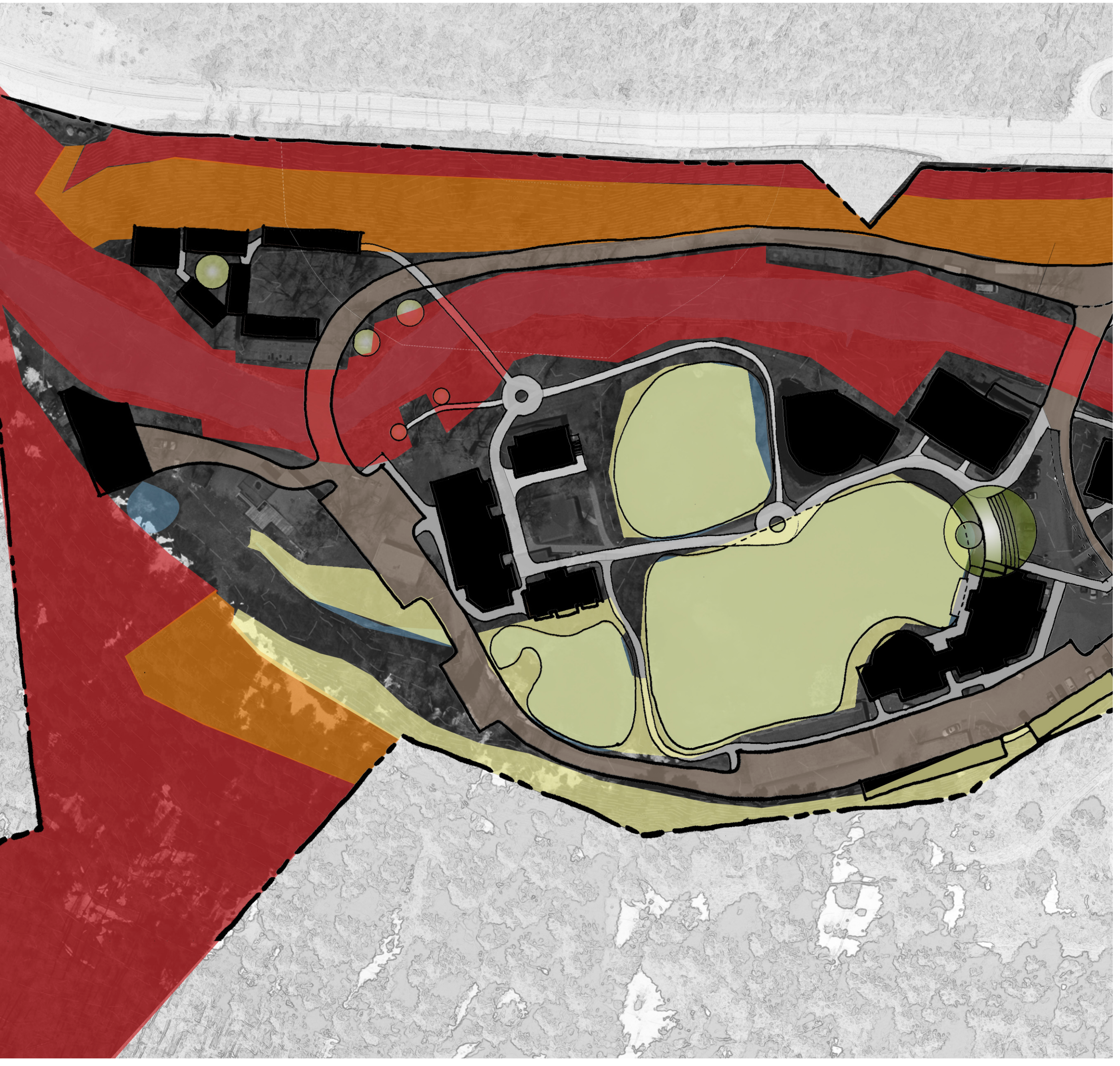


Fig. 71: restored and protected riparian and wetland areas



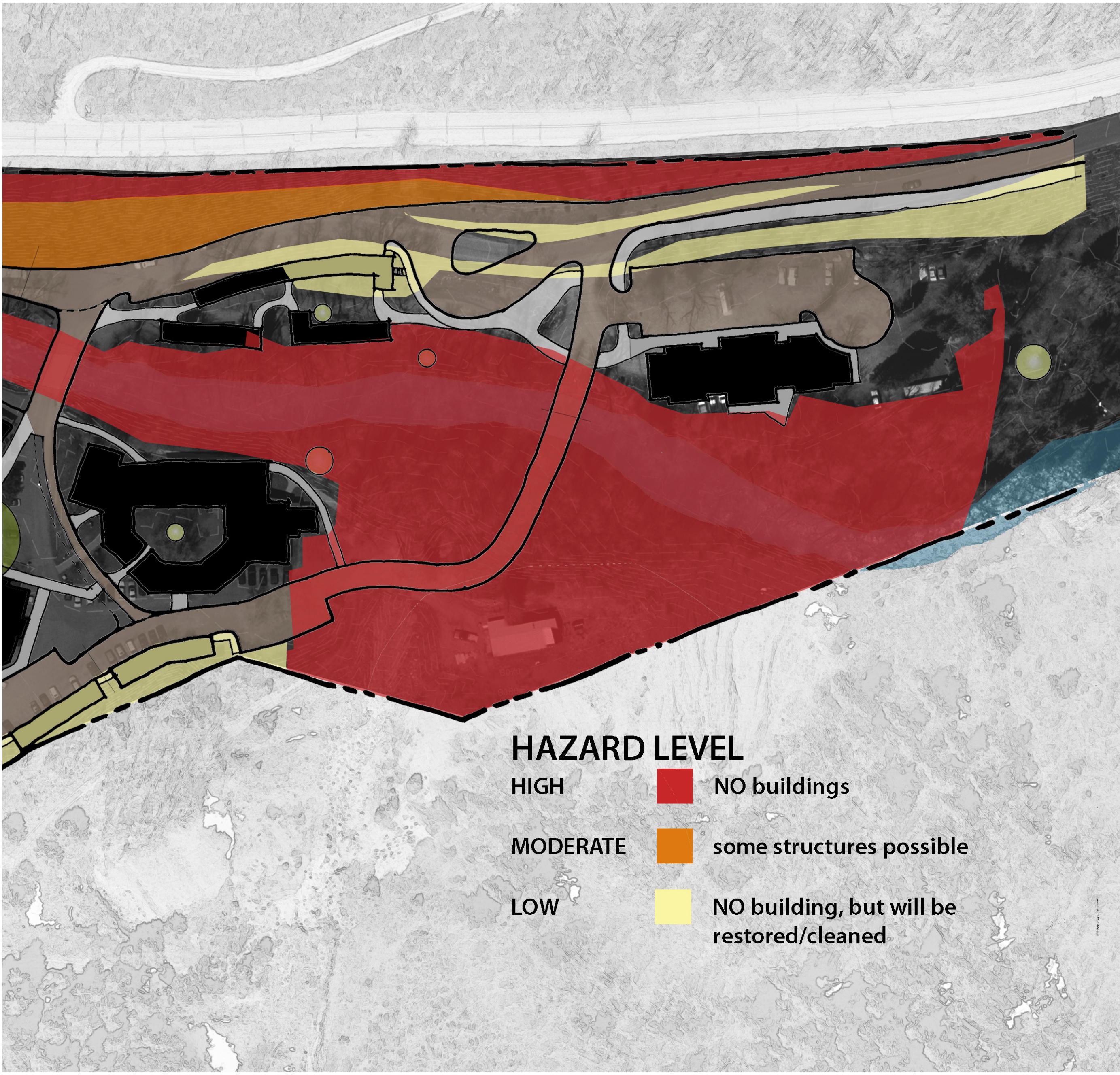


Fig. 72: developable area on the campus

Source: www.flickr.com 2009

Source: www.flickr.com 2009

Fig. 73: existing site and building character to be preserved through the design of the campus

enhance and preserve the quality of castle creek

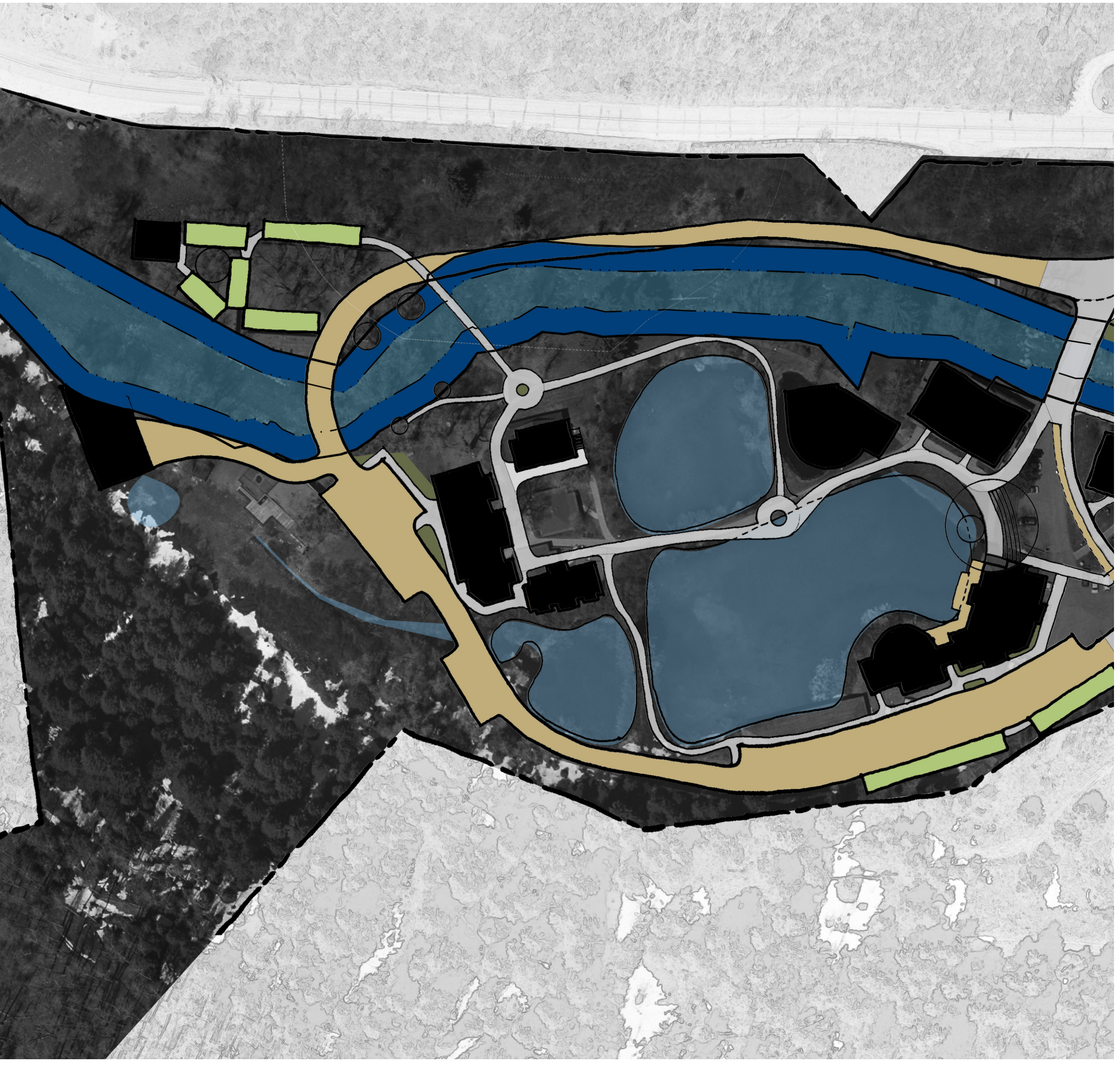
As required by Pitkin County variance, the 20 foot buffer around the creek has been respected. It has been and enlarged in areas determined to be vulnerable (*Fig. 74*). Vulnerability is based on the quality of riparian vegetation, greater than 30% slopes, and floodplain.

The proposed program reduces the number of vehicles staying on site by decreasing the number of parking spaces. This allows for less impervious pavement reducing runoff into the creek. To help clean what runoff there is certain best management practices (BMP's) have been proposed for the campus.

Vegetated swales are located in transition areas between pavement and the Castle Creek. Pervious pavement is proposed in the restricted access and low traffic areas to assist in stormwater management. Green roofs are proposed on all practice rooms. The practice structures are most suitable because the slanted roof design allows for vegetated surface more than other buildings on campus. Unfortunately, elements such as cisterns can not be implemented due to the very strict water laws in Colorado. Development can slow water infiltration, but one can not capture water.

use of materials

In accordance with the Sustainable Sites Initiative, the materials chosen for the campus are largely local and do not require extensive shipping methods. For instance, much of the stone used in paving will be sand stone. In addition, the large boulders proposed for seating and retaining will be collected from on-site in the rock fall areas. The landscape materials used were chosen for their existing presence on the site and little need for irrigation. Although it is not specified in this proposal, it is assumed that all new construction will be built to the LEED standard and existing structures will be retrofitted to reflect minimal energy use.



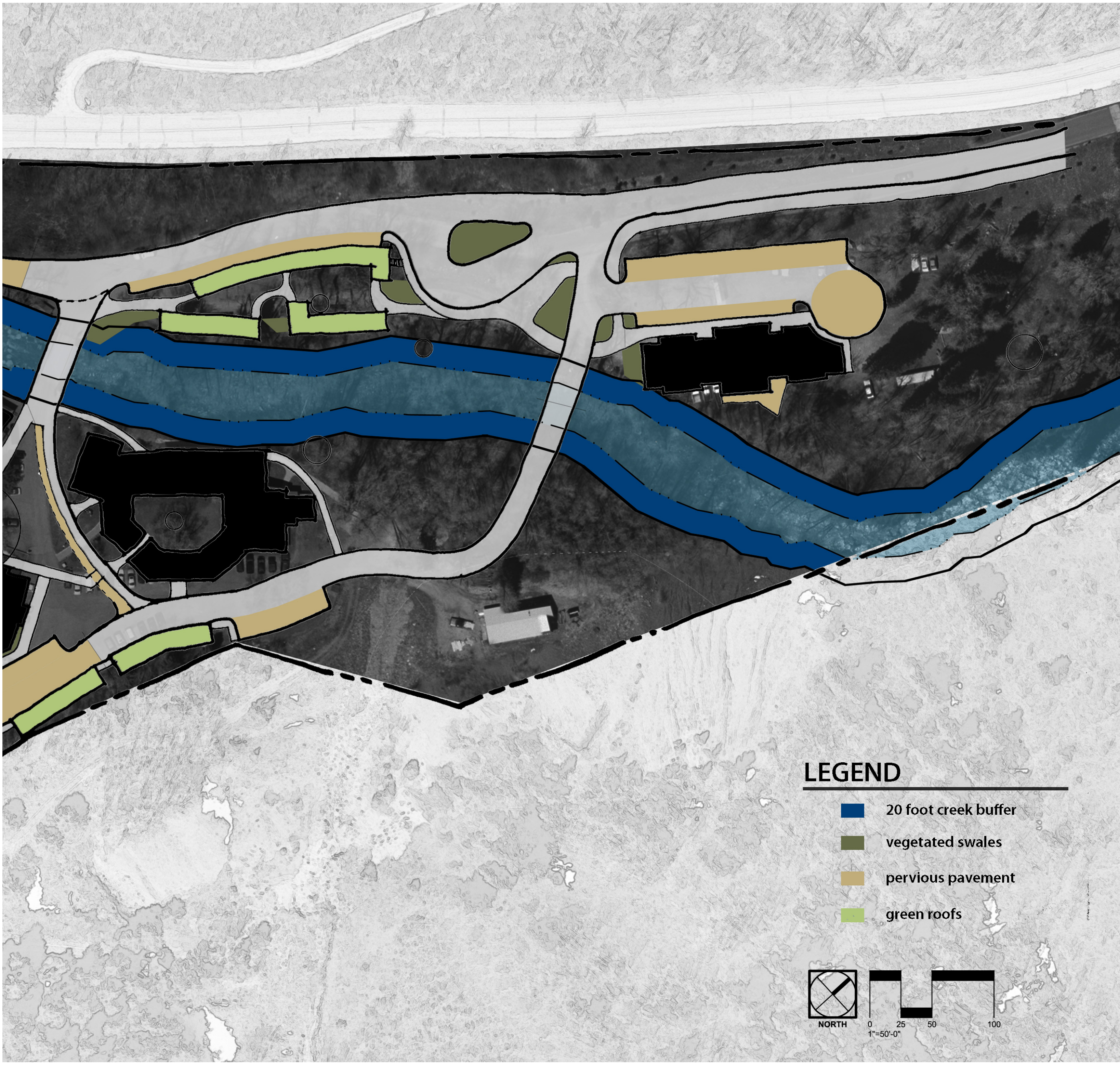
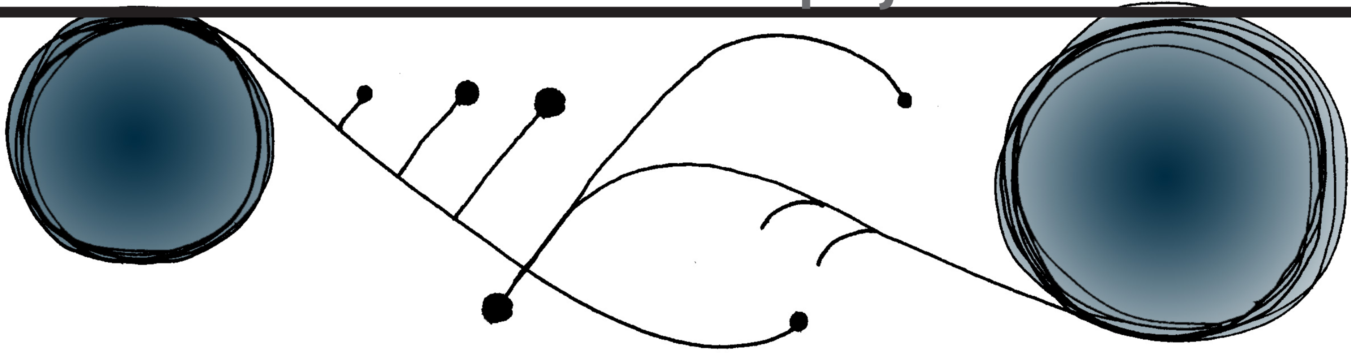


Fig. 74: location of 20 foot buffer and Best Management Practices on the campus

project conclusions



Acoustics is an area rarely studied in relation to its effect on outdoor environments. Bringing together these two realms of knowledge has resulted in a rich and complex project, as well as establishing a new approach to the design of musical institutions like the Aspen Music Festival and School. It is the overall goal of this project and report to influence the field of landscape architecture by making the effect of sound outdoors just as important and positive as aesthetics.

The design of a high-elevation, music centered campus in one of the most regulated counties in the United States has presented multiple challenges. However, researching the fundamentals of the science of sound, understanding the setting of the site, and utilizing sustainability show that as positive result can be attained.

Although acoustic quality of these spaces cannot be proven until built, there are certain measures designers can take to ensure the best possible acoustic conditions.

Limitations of this project arose while completing the comparative sound study. Due to limited funds and time it was not feasible to conduct the study on the actual Castle Creek Campus. Doing so would have been the most desirable method. However, I hope to rectify this in the future. It is my intention to continue the research of the comparative sound study in a more in-depth manner, with a higher quality of equipment, and physically record the conditions on the Aspen campus.

In addition, involving other disciplines (such as physicists and mathematicians) in the study would be greatly beneficial due to my very basic knowledge of acoustics. Their expertise would provide more credibility and depth to the study. I feel that these additions to the study will greatly benefit the richness and quality of the design of the Castle Creek Campus.

glossary

Adapted (or introduced) Plants - Plants that reliably grow well in a given habitat with minimal attention from humans in the form of winter protection, pest protection, water irrigation, or fertilization once root systems are established in the soil. Adapted plants are low maintenance but not invasive. (USGBC, 2007)

Alternative-Fuel Vehicles - Vehicles that use low-polluting, non-gasoline fuels such as electricity, hydrogen, propane or compressed natural gas, liquid natural gas, methanol, and ethanol. Efficient gas-electric hybrid vehicles are included in this group for LEED purposes. (Haselbach, 2008)

Apparent Source Width - This occurs when the music performed in a hall appears to the listener to emanate from a source wider than the visual width of the actual source. This attribute is sometimes abbreviated as ASW. *(Beranek 1996, 23)*

*Area Median Income - T*he median, or middle, income of a county as defined and available from the U.S. Department of Housing and Urban Development. (USGBC, 2007)

Acoustics - The qualities or characteristics of a room, auditorium, stadium, etc., that determine the audibility of fidelity of sounds in it. (dictionary.com)

Acoustic Glare - If the side walls of a hall or the surfaces of hanging panels are flat and smooth and are positioned to produce early sound reflections, the sound from them may take on a brittle or hard or harsh quality, analogous to optical glare. (Beranek 1996, 24)

Ambient Sound - The sounds of an environment most people don't notice such as bird's chirping, leaves rustling, or dripping water.

Background Noise Level - the noise level in the acoustic environment, usually excluding the noise source of interest. (Cowan 1993, 272)

Best Management Practices (BMP) - A practice or combination of practice that are determined to be an effective, efficient, and practicable (including technological, economic and institutional considerations) means of controlling point and nonpoint pollutants at levels compatible with the environment. (ASLA 2007, 80)

Biking Network - A continuous network consisting of one or more of the following: bicycle lanes or trails at least 5 feet wide or roads designed for a speed of 10 miles per hour or slower. (USGBC, 2007)

Biodiversity - The variety of life in all forms, levels, and combinations, including ecosystem diversity, species diversity, and genetic diversity. (Haselbach, 2008)

Blackwater - Non industrial wastewater containing significant food residues, high concentrations of toxic chemicals from household cleaners, and/ or toilet flush water. (ASLA 2007, 80)

Blend - A mixing of the sounds from the various instruments of the orchestra so that the listener fins them harmonious. (Beranek 1996, 24)

Brilliance - A bright, clear, ringing sound, rich in harmonics. In a brilliant sound the treble frequencies are prominent and decay slowly. This means that the high frequencies are diminished only by the natural absorption of the sound in the air itself. The sound may become overly brilliant if electronic amplification is improperly used. (Beranek 1996, 24)

Buildable Land - *T*he portion of the site where construction can occur. When used in density calculations, the calculation for buildable land excludes: public streets and other public rights of way, and land excluded from development by law or other prerequisites of LEED for Neighborhood Development. (USGBC, 2007)

C*arpool* - An arrangement in which two or more people share a vehicle for transportation. (Haselbach, 2008)

Clarity - The degree to which the discrete sounds in a musical performance stand apart from one another. It depends critically on musical factors and the skill and intention of the performers, but it also closely related to the acoustics of the room. (Beranek 1996, 23)

Community - An interacting population of individuals for working together to carry out the commissioning process. (Haselbach, 2008)

Continuous Sound - sound having a steady, nonimpulsive nature. (Cowan 1993, 272)

D*ead*- acoustical description of a space that does not alter the music or sound in any way. (Cowan 1993, 272)

Development Footprint - The total land area of a project site covered by buildings, streets, parking areas, and other typically impermeable surfaces constructed as part of the project. (USGBC 2007)

Diffraction - the act of sound waves traveling around barriers, especially pronounced when the sound wavelength size is comparable the or greater than the dimensions of the barriers. (Cowan 1993, 272)

Diffusion - the act of sound waves spreading out over a wide area after reflecting off of a convex or uneven surface. (Cowan 1993, 272)

E*cho* - a delayed reflection sufficiently loud to annoy the musicians on stage or the listeners in the hall. (Beranek 1996, 25)

Ecosystem - a basic unit of nature that includes a community of organisms and their nonliving environment linked by biological, chemical, and physical processes. (Haselbach 2008, 369)

Ensemble - the ability of the performers to play in unison, to initiate and release their notes simultaneously so that the many voices (or instruments) sound as one. (Beranek 1996, 25)

Erosion - A combination of processes in which materials of the earth's surface are loosened, dissolved, or worn away and transported from one place to another by natural agent (such as water, wind, or gravity). (Haselbach 2008, 369)

F*ull Cutoff Luminaire* - A full cutoff luminaire has zero candela (0-cd) intensity at an angle of 90 degrees above the vertical axis (nadir) and at all angles greater than 90 degrees from nadir. Additionally, the candela per 1000 lamp lumens does not numerically exceed 100 (10 percent) at an angle of 80 degrees above nadir. This applies to all lateral angles around the luminaire. (Haselbach 2008, 370)

G*raywater* - waste water from bathroom, kitchen, and laundry activities, esp. as it may be recycled for toilet and outside water uses. (dictionary.com 2008)

Habitable Building - A structure that is intended for living, working, or other types of occupancy. Habitable structures do not include buildings such as garages and pump stations. (USGBC 2007)

Harmonic - a positive integer multiple of the fundamental acoustic resonance frequency, including the fundamental. The first harmonic corresponds to the fundamental and the second harmonic corresponds to the first overtone. (Cowan 1993, 273)

Immediacy of Response - The manner in which the first reflections from surfaces in the hall arrive back at the musician's ears. (Beranek 1996, 25)

Impervious Surfaces - surfaces that promote runoff of precipitation volumes instead of infiltration into the subsurface. The imperviousness or degree of runoff potential can be estimated for different surface materials. (Haselbach 2008, 371)

Intimacy - A hall that is small has visual intimacy. A hall is said to have "acoustical intimacy" if music played in it gives the impression of being played in a small hall. (Beranek 1996, 22)

*Invasive Plant*s - Plants that may be either indigenous or non-indigenous species or strains that are characteristically adaptable, aggressive, have a high reproductive capacity and tend to overrun the ecosystems in which they inhabit. (USGBC 2007)

Landscapes - the visible features of an area of land, including physical elements such as landforms, living elements of flora and fauna, abstract elements such as lighting and weather conditions, and human elements such as human activity or the built environment. (SSI 2007, 8)

Land development and management practices - all land-related practices involved in the development and management of a site, including design, construction, operations, and ongoing maintenance. For simplicity purposes in this report, these are described as "land practices." (SSI 2007, 8)

LEED ND - Leadership In Energy and Environmental Design in Neighborhood Development. (USGBC 2007)

Listener Envelopment - Describes a listener's impression of the strength and directions from which the reverberant sound seems to arrive. LEV is judged highest when the reverberant sound seems to arrive at a person's ears equally from all directions -- forward, overhead, and behind. (Beranek 1996, 23)

M*usic* - an agreeable sound; vocal, instrumental, or mechanical sounds having rhythm, melody, or harmony; the science or art of ordering tones or sounds in succession, in combination, and in temporal relationships to produce a composition having unity and continuity. (Merriam-Webster Dictionary 2003)

N*ative Plants* - Plants that have adapted to a given area during a defined time period and are not invasive. In America, the term often refers to plants growing in a region prior to the time of settlement by people of European descent. (USGBC 2007)

Noise - unwanted sound. (Cowan 1993, 274)

P*reviously Developed Site* - A site consisting of at least 75% previously developed land. (USGBC 2007)

R*eflection* - the act of sound bouncing off of a partition, usually occurring from smooth, hard surfaces. (Cowan 1993, 275)

Resonance - the generation of standing waves within a space at specific frequencies that correlate certain fractions of wavelengths, and integer multiples of them, with the dimensions of the space. (Cowan 1993, 275)

Reverberation - Refers to sound that persists in a room after a tone is suddenly stopped. (Beranek 1996, 24)

Reverberation Time - The number of seconds it takes for a loud note to decay to inaudibility after being stopped. (Beranek 1996, 23)

Site - a contiguous area of land upon which a project is developed or proposed for development; an area of property that is experiencing land development and management. (SSI 2007, 8)

Site Sustainability - design, construction, operations and maintenance practices that meet the needs of the present without compromising the ability of future generations to meet their own needs. (SSI 2007, 9)

Soundscape - a places sonic, or acoustic, environment, with the receiver, or listener, at the center of the sonic landscape (Proteous and Mastin 1985)

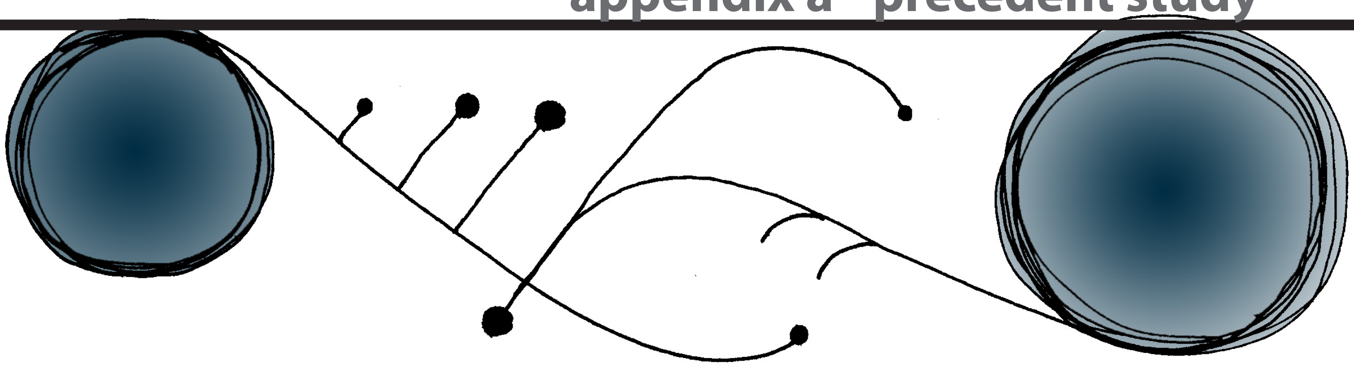
Spectral Frequency Display - The spectral display shows audio by its frequency components, where the x-axis (horizontal ruler) measures time and the y-axis (vertical ruler) measures frequency. This view lets you analyze audio data to see which frequencies are most prevalent. Colors represent amplitude, ranging from dark blue for low amplitude to bright yellow for high amplitude. (Adobe Soundbooth Help 2007)

Texture - the subjective impression the listeners derive from the patterns in which the sequence of early sound reflections arrive at their ears. (Beranek 1996, 25)

Warmth - In music it is described as liveness of the bass, or fullness of the bass tones (between 75 and 350 Hz), relative to that of the mid-frequency tones (350 to 1,400 Hz). (Beranek 1996, 23)

Waveform - A term that describes the visual representation of an audio signal, displayed as amplitude across time in Soundbooth. (In acoustics, waveform refers to a sound wave of a specific frequency. (Adobe Soundbooth Help 2007)

appendix a - precedent study



PRECEDENT STUDY

In order to better understand my process and method of design for the Castle Creek Campus, it was necessary to do precedent studies relevant to the subjects being studied. Those subjects are based upon the dilemma and thesis discussed in the Design Intent and include (1) Placement and (2) Design. These are two separate, yet equally important aspects of the CCC project. My thesis states that “carefully placing and designing outdoor performance and practice spaces for the students” will address the issues related to acoustics and sustainability.

Placement (master plan scale)

The placement of the outdoor performance spaces in these precedents are analyzed by three main criteria:

- Sound Mapping (Hedfors, 2003)
- Types/Layout of space
- Sustainable Sites Guidelines

Design (detailed site scale)

The design of acoustically sound and sustainable performance spaces is determined by:

- Acoustic Standards/Terms
- Material selection
- Sustainable Sites Guidelines - dealing with the detail site scale.

Tanglewood Music Festival

Location: Lenox, Massachusetts
Date designed: "The Shed" - 1937, site was never comprehensively designed because it was originally private residences.
Size: 500 Acres
Designers: Engineer Joseph Franz
Client: Tanglewood Music Center Trustees

Physical Context

The TMC site is nestled on the hillside just south of Lenox, MA in Berkshire County. It is bordered on three sides by arterial roads. These are not heavily traveled, unless the TMC is having an event. The entire site slopes slightly to the south west down to Stockbridge Bowl Lake. There are spectacular views toward the lake from the campus across the landscape.

Fig. A1: site photo looking across the lawn from "The Shed" toward the Lake (www.bso.org, 2008)

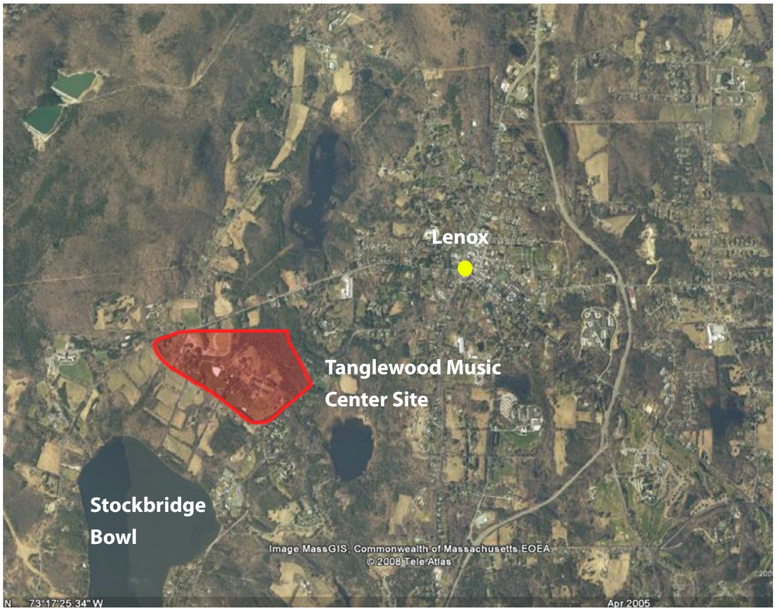
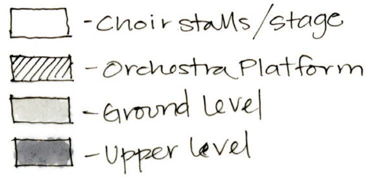


Fig. A2: site context *Source: GoogleEarth 2008*

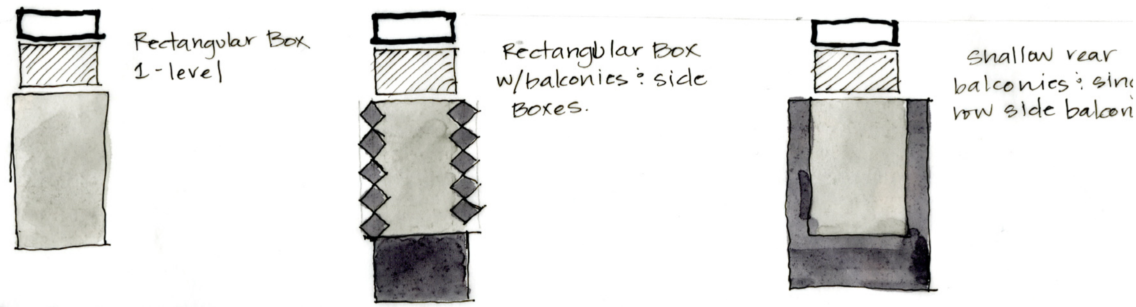
TYPES OF PERFORMANCE SPACES:

• 3 Basic types:

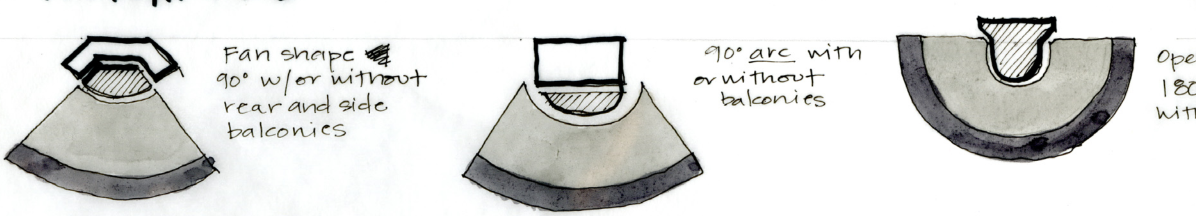
1. Rectangular
2. Fan-shaped
3. Horseshoe



1. RECTANGULAR



2. FANSHAPED



3. HORSESHOE

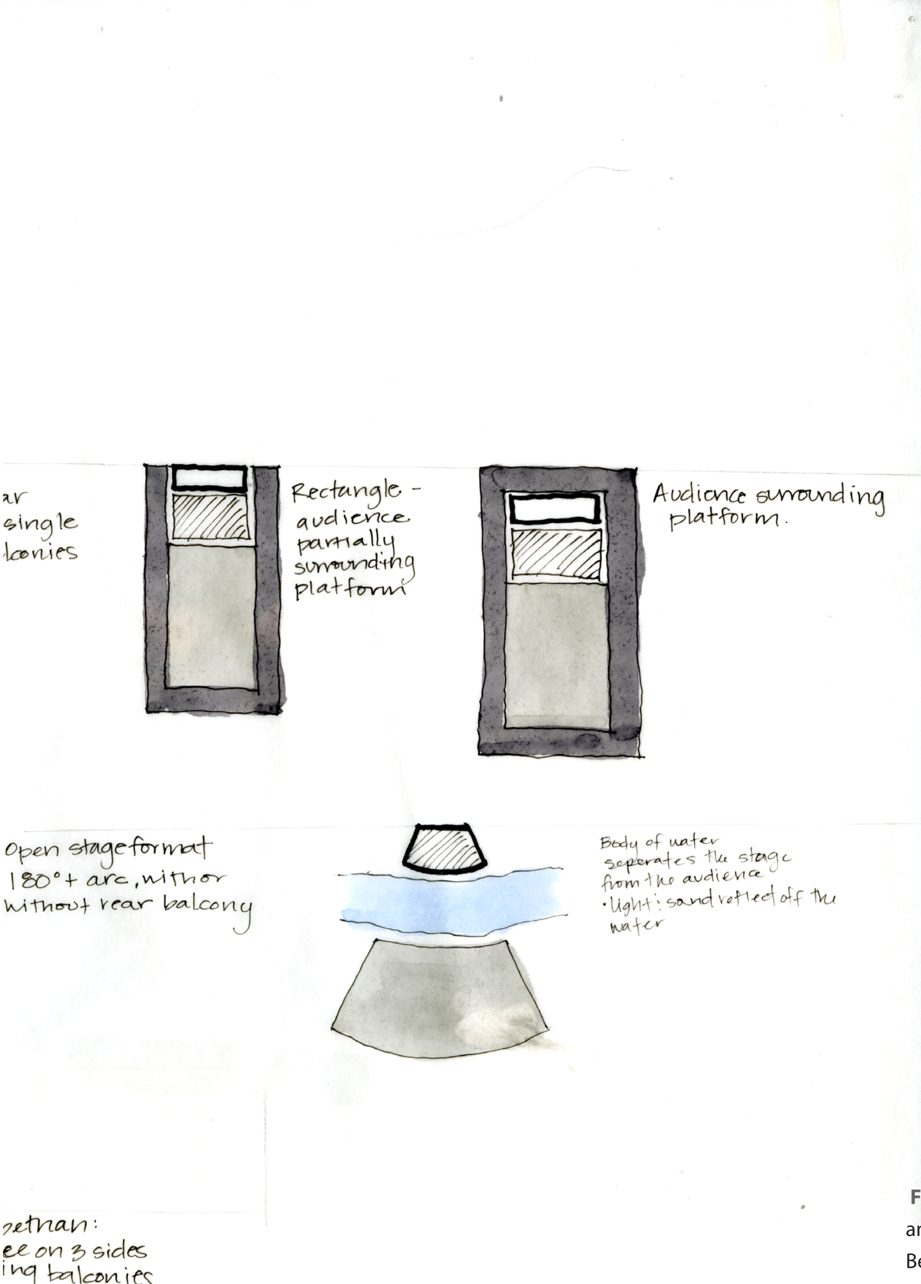


Fig. A3: types of concert hall and amphitheater layouts coming from Beranek's three basic types and categorized further. These types are all arrangements that could be applied to the CCC site, but later analysis will determine which type is the most appropriate for the specific site conditions.
Source: Appleton 2008

Historical Context

The 500 acres are spread across two formerly privately owned estates. The specific time line is as follow: (www.bso.org, 2008)

- **1841** - Samuel G. Ward purchased the land
- **1849** - William Aspinwall Tappan purchased neighboring parcel
- **1850** - Tappan rented small red house to Nathaniel Hawthorne who wrote the children's book *The Tanglewood Tales*.
- **1934** - Henry Hadley, of the New York Philharmonics, became interested in starting a music festival in the Berkshires.
- **1934** - Members of the New York Philharmonic performed three outdoor concerts which were given under a large tent for an audience of nearly 15,000.
- **1936** - The Festival Committee then invited Serge Koussevitzky and the Boston Symphony Orchestra gave its first performance in the Berkshires, at Holmwood.
- **1936** - Mrs. Gorham Brooks and Miss Mary Aspinwall Tappan offered their family estate, Tanglewood as a gift to Koussevitzky and the orchestra.
- **1937** - the first concert at Tanglewood takes place.
- **1938** - The Shed is inaugurated.
- **1940** - The Berkshire Music Center (now the Tanglewood Music Center) begins its operations and Randall Thompson's commission Alleluia is performed.
- **1959** - In 1959, collaboration between the acoustical consultants Bolt, Beranek, and Newman and architect Eero Saarinen and Associates, results in the installation of the unique Edmund Hawes Talbot Orchestra Canopy.
- **1986 -** With the Boston Symphony Orchestra's acquisition in 1986 of the Highwood estate adjacent to Tanglewood, the public grounds are expanded by over 40%.
- **1994** - On July 7, Seiji Ozawa Hall is inaugurated.

“The Shed”

The Shed is on outdoor performance structure., which is the primary concern of this study. It is steel frame building with a roof structure for weather purposes and open air sides. The structure’s volume is 1,500,000 ft^3 and can hold up to 5,121 listeners under the roof and another 10,000 on the lawn outside due to the superior amplification system. Due to “muddy” acoustics, the stage area was redesigned in 1954 by Bolt Beranek and Newman. The newly designed enclosure was 50% open, comprised of 26, low non-planar triangular panels varying in width from 7 to 26 ft.

Fig. A4: site photo looking toward "The Shed" from the lawn area (www.bso.org, 2008).

Fig. A5: The signature "tangles" trees of the music center lie within the lawn area adding a sculptural element to the aesthetic.
Source: www.bso.org 2008

Fig. A6 (Top Left): View inside The Shed from side toward the stage.
Source: www.bso.org, 2008

Fig. A7 (Top Right): Image of one of the many orchestra performances that take place in The She.
Source: www.bso.org, 2008

Fig. A8 (Middle Right): View across the grounds.
Source: flickr.com/photos/78799744@N00/2631310929/, 2008

Fig. A9: One of the original residences on the Tanglewood Campus currently being used by the organization.
Source: www.bso.org, 2008

Placement Inventory

Analysis first began by diagramming the soundscape of the entire campus to expose any relationships between the sounds heard in certain areas of the campus and the location of The Shed. It was discovered that The Shed is nestled in a relatively natural landscape. There are very few if any **noises** to disturb the intended sounds of the music. The structure is buffered from any traffic noise coming from the surrounding three streets by densely wooded areas and other structures.

The types of vegetation surrounding the structure also support this baffling effect from any outside noise. In addition, the shape or organization of the space uses the topography of the site for organization. The structure is shaped like a fan, which is typically the form for outdoor performance spaces (Appleton 2008).

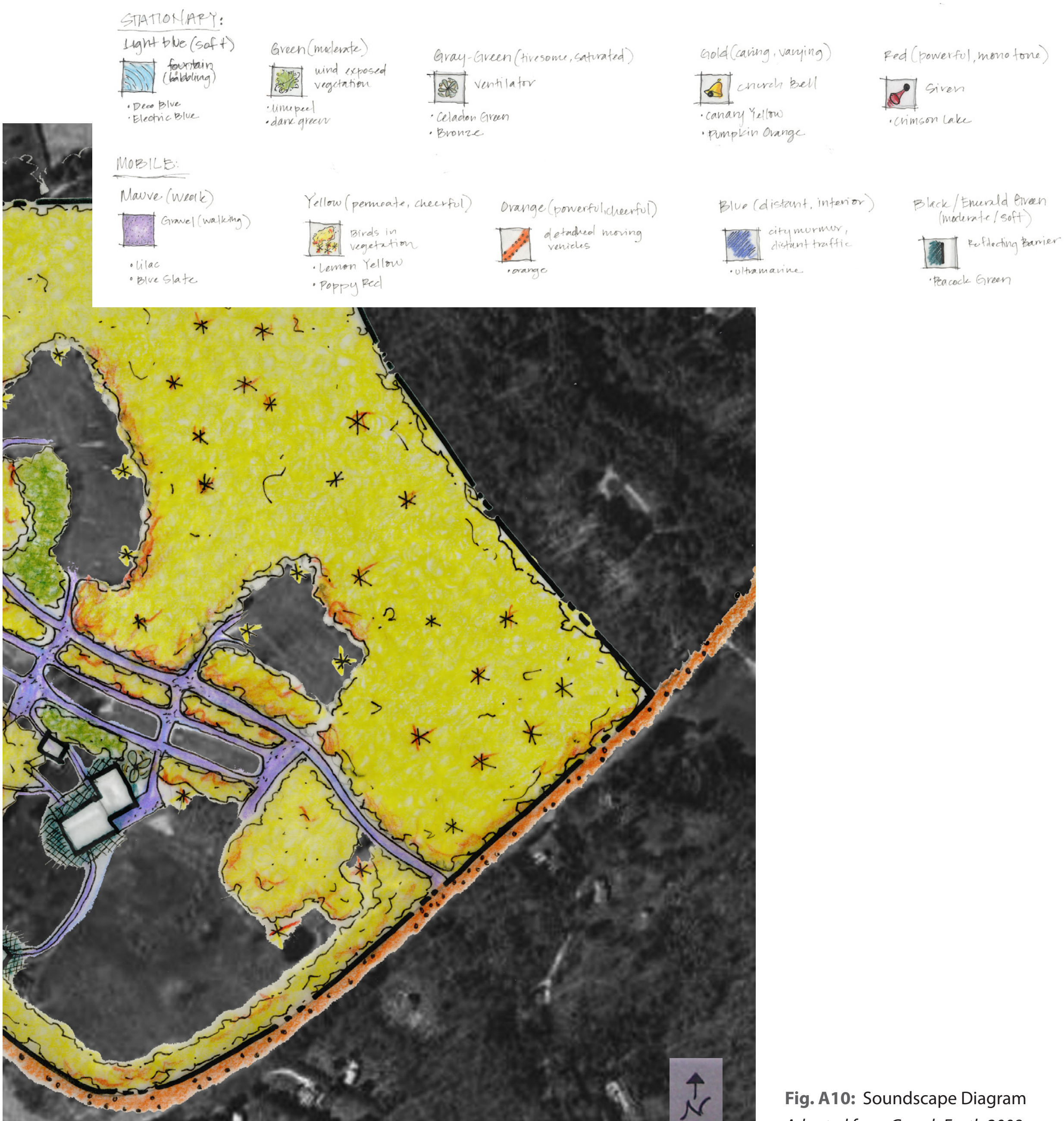
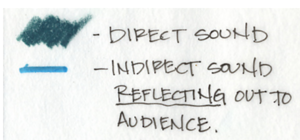


Fig. A10: Soundscape Diagram
Adapted from GoogleEarth 2008

Design Inventory

The Design of The Shed uses many of the acoustical standards discussed by White and Beranek. The panels on the stage ceiling reflect about half of the early sound energy down onto the audience, also known as acoustic glare. This reflection arrives shortly after the direct sound which as discussed previously, is the key to superior sound quality in concert halls (Beranek, 1996, 111). The sheer size of the hall makes the fact that the reverberant sound energy is proportionally very close to the direct sound energy, or short time-delay. The use of large vegetation within the lawn area creates a diffraction of sound. Such an interaction is displayed in the diagram on page 36.



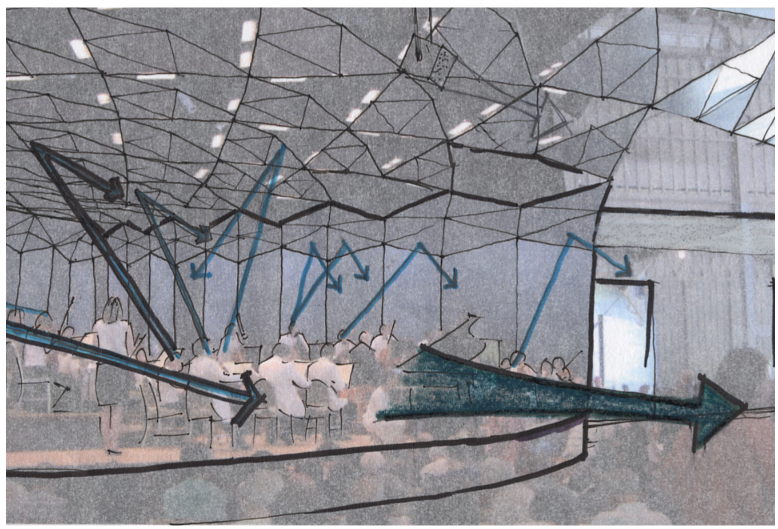


Fig. A11: reflection and Diffusion of sound by the panels of the stage
Diagram by author

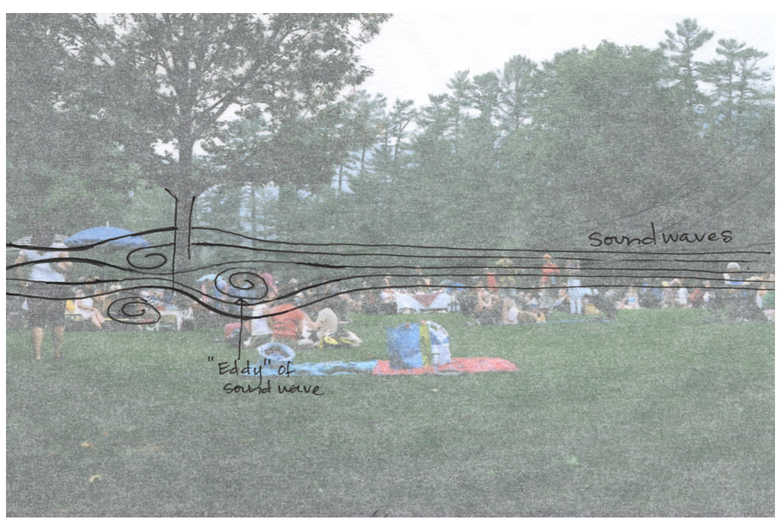
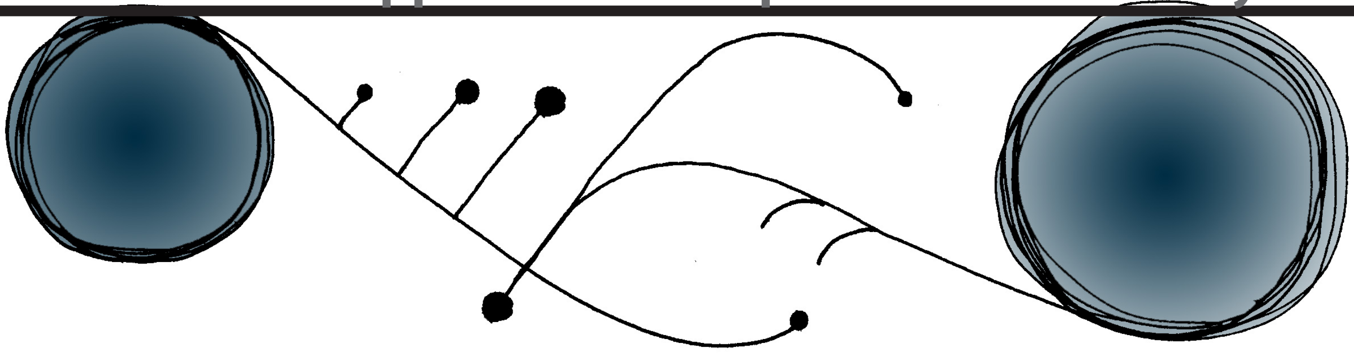


Fig. A12: diagram showing the effect of the large vegetation on the movement of sound through the air.
Diagram by author

Fig. A13: vegetation type diagram displays the different vegetation sizes and densities used on-site.

appendix b - comparative sound study



In order to gather information regarding the acoustic quality of the Castle Creek (CC) Campus, a comparative study was done on the Kansas State University (KSU) Campus due to the expenses associated with doing such a study on the Castle Creek Campus itself. The purpose of the study was to classify and determine outdoor acoustical quality of specific spaces on the Castle Creek Campus.

method description

The method for doing such a study began with determining variables which effect sound on the Castle Creek campus. These variables were chosen based on 4 site visits at various times of the year, personal knowledge of the campus and aerial/site photos. These variables were then applied to the KSU campus to identify sites which would accurately represent the variables themselves as well as the physical conditions of the Castle Creek Campus. See the inventory section pages 49-67. The sites were chosen because of their ability to represent the variables. Digital recordings of Christie Murman playing the fiddle were then taken at each site on the KSU campus using a digital audio recorder. These recordings were then analyzed both qualitatively and quantitatively in regards to the extent of background noise interruption. Each variable was classified based on the analysis into a "Excellent," "Good," "Fair," or "Poor" category.

Space Type Identification

The first step to the comparative study was to observe the Castle Creek Campus to determine what types of spaces were on the property. Site photographs and aerials as well as personal knowledge of the campus were the primary source of information. The term "spaces" refers to an area which is defined by the physical characteristics within and surrounding it. Each space is inherently different from other areas on campus. In order to define the spaces the spacial characteristics were taken into consideration. It was from these observations that specific variables were identified.

Variable Identification

Variables were determined by observing what physically contributed to the individuality of the spaces. These represent these physical characteristics and chosen for their potential to effect acoustics in outdoor environments. Identifying variables allowed for the comparison between the two campuses.

- *High Canopy* (~40' height) versus *Low Canopy* (<12' height) - because height of canopy, much like ceiling height, can effect the reflection, resonance and reverberation of the intended sound as described by Frederick White.
- *Dense Canopy* (~80% coverage) versus *Open Canopy* (~30% coverage) - because density can also effect the reflection, resonance and reverberation of the intended sound much like materials of walls and percent of ceiling left open.
- *Open Field* (0 sides) versus *Mounded Landform* (1 to 2 sides) versus *Courtyard* (4 sides) - for the size smaller practice spaces, what amount of enclosure provides the most resonance and reverberation? This would be strictly for small ensembles of students (one to 10 people), not for performance purposes involving and audience.
- Rushing Water versus Calm Water - how much does rushing water effect the legibility of the intended sound? What effect does water traveling across a clam body of water have on the intended sound?
- Hard Materials versus Soft Materials - this ties closely to what White and Beranek recommend in their texts in terms of the effect on sound absorption and reflection, but focuses on the outdoor application where "soft" refers to grass or fabric and "hard" refers to concrete or glass.

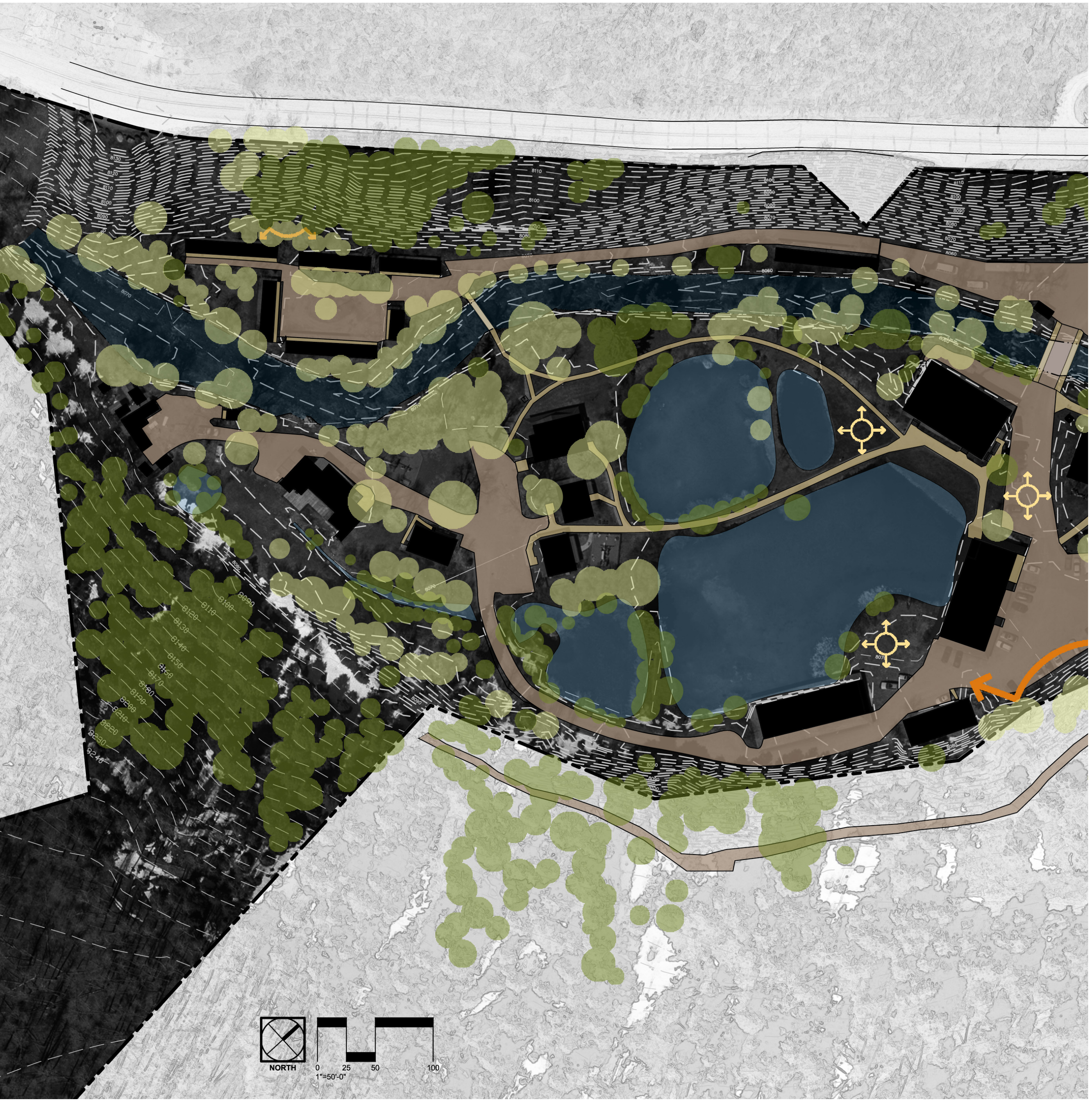

NORTH
0
25
50
100
1"=50'-0"

Fig. B1: variable Identification Map of the Castle Creek Campus showing the locations of each variable on the campus.

KSU Comparable Sites







After identifying the variables to be tested it was necessary to determine sites on the KSU campus which were similar to those identified on the Castle Creek Campus. The sites chosen are similar in their physical characteristics to the each variable. This exercise allowed for the grouping of certain variables which seemed to consistently relate to one another. For example, "High" and "Open" canopy's were often one in the same on both campuses, likewise for "dense" and "low." The sites chosen are as follows:

- *Site 1 - "1 to 2 sides"*: the northern slope of Old Stadium. Contains the bowl-like land formation which is common on the Castle Creek Campus due to the severe slopes. These slopes could be utilized in the summer when the Aspen Music Festival and School is in session and there are no avalanche risks.
- *Site 2 - "Materials"*: the western end of Bosco Plaza has a small concrete retaining (approximately three (3) feet height) wall with dense evergreen plantings approximately two (2) feet in height. It provides a perspective on the blending of material types for backdrops in performance and practice spaces.
- *Site 2 - "Rushing Water"*: near the fountain on the Bosco Plaza. In close proximity while the fountain is running, the resulting sound is similar to that of the rushing Castle Creek.
- *Site2 - "Hard" and "0 sides"*: the eastern side of Bosco Plaza chosen for the ground plane materials of concrete and the limited vertical obstructions.
- *Site 3 - "Soft" and "0 sides"*: center of the Anderson Lawn has a turf grass surface with no obstructions within more than a fifty foot radius.
- *Site 4 - "High" and "Open"*: grove of very tall trees near the President's House, similar to the Cottonwoods which are very common on the Castle Creek Campus.
- *Site 5 - "Low"*: under a willow tree fifteen (15) feet from the creek creates a very low canopy nearly enclosing the space similar to many of the low-growing willows on the Castle Creek Campus. This would not fall under "dense" or "open" because the canopy was somewhere in the middle in terms of percent coverage.

- *Site 5 - "Low" and "Dense"*: southeast of the International Student Center under the massing of honeysuckle. These large shrubs provide thick canopy cover and are only about eight to ten feet tall, just enough to stand under.
- *Site 6 - "4 sides"*: the completely enclosed courtyard in Waters Hall contains some small trees and a mixture of concrete, glass and metal walls/windows. This provides a mixture of surface types contributing to the reflection and absorption of sound.

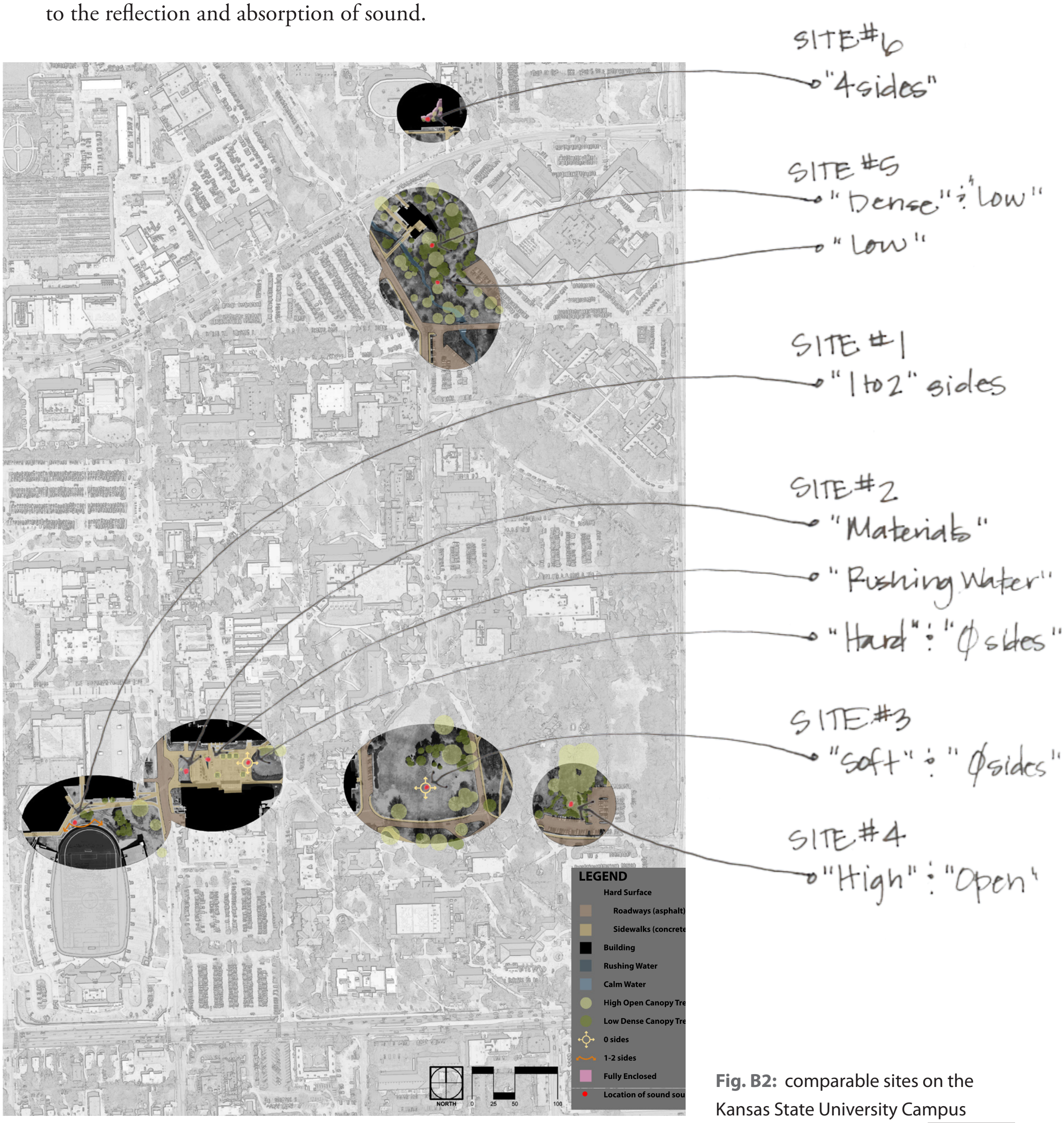


Fig. B2: comparable sites on the Kansas State University Campus

Research

Conducting the study out in the field required preparation in order to make sure the data was valid and comparable. Some control factors needed to be determined. The distance from the source of the sound (fiddle player) was set to approximately six (6) feet. The time of day was to be reasonably calm in terms of pedestrian traffic and interaction, therefore, no recordings at site #2 (Bosco Plaza) were to be taken during passing period to avoid unusually high dB levels of background noise which would not occur on the Castle Creek Campus during performances. In addition, it was necessary to find someone who was willing to walk around campus and play an instrument for the recordings. For this, Christie Murman, a very talented fiddle player was asked to help.

In order to record what was happening in the physical environment at the time the recordings took place a data sheet was developed (see Appendix B). The data sheets allowed things like the number of birds, crickets, surface materials, and weather conditions to be documented.

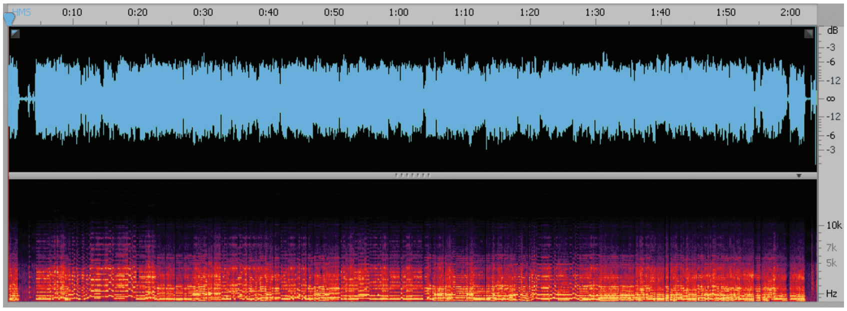
Christie was to be recorded playing the fiddle for a minimum of one (1) minute at each site, for each variable. Some recordings are longer due to interference (i.e. someone asking what we were doing).

Later, recordings were taken without Christie playing for reference to see how much the background noise effected the intended sound. This would prove useful in the quantitative analysis.

Quantitative Analysis of Recordings

The first step to analyzing the recordings done on the KSU Campus was to observe the waveforms and spectral frequency displays using audio editing software. The software allowed for visually observing the effect of background noise on the recording by showing the decibel (dB) level of the recordings. The following displays the differences between the recordings with and without the fiddle playing. It is assumed that the recordings without the fiddle represent average levels of background noise at each site, for each variable.

Before looking at each variable it is necessary to describe what the graphs are showing. The audio software used provides excellent and simple definitions.



Waveform (dB)

Spectral Frequency Display (SFD)

Several measurements describe sound **waveforms**:

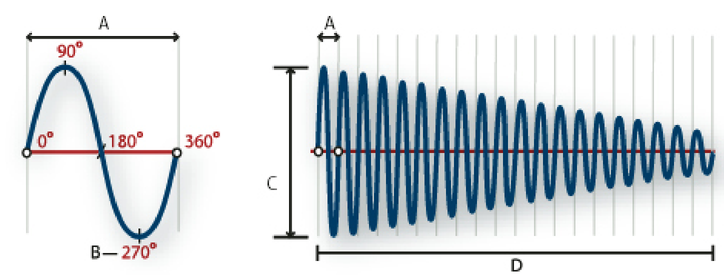
Amplitude Reflects the change in pressure from the peak of the waveform to the trough. High-amplitude waveforms are loud; low-amplitude waveforms are quiet.

Cycle Describes a single, repeated sequence of pressure changes, from zero pressure, to high pressure, to low pressure, and back to zero.

Frequency Measured in hertz (Hz), describes the number of cycles per second. (For example, a 1000-Hz waveform has 1000 cycles per second.) The higher the frequency, the higher the musical pitch.

Phase Measured in 360 degrees, indicates the position of a waveform in a cycle. Zero degrees is the start point, followed by 90º at high pressure, 180º at the halfway point, 270º at low pressure, and 360º at the end point.

Wavelength Measured in units such as inches or centimeters, is the distance between two points with the same degree of phase. As frequency increases, wavelength decreases.



A single cycle at left; a complete, 20-Hz waveform at right
***A.** Wavelength **B.** Degree of phase **C.** Amplitude **D.** One second*

Fig. B3: example wavelength diagram
Source: Adobe Soundbooth Help 2008

Spectral Frequency Display

The spectral display shows audio by its frequency components, where the x-axis (horizontal ruler) measures time and the y-axis (vertical ruler) measures frequency. This view lets you analyze audio data to see which frequencies are most prevalent. Colors represent amplitude, ranging from dark blue for low amplitude to bright yellow for high amplitude.

The spectral display is perfect for removing unwanted sounds, such as clicks, coughs, buzz, hum and other artifacts. This is known as frequency-space editing. The unwanted sounds are visible due, typically, to the concentration of high frequency colors (purples and blues)

Control Recording

The Control recording was done in the soundbooth located at Hale Library on the KSU Campus for the purposes of providing the highest quality sound the device used could produce. This control recording also provided a base for qualitatively analyzing all other variables recorded. The control recording shows no background interference in the form of spikes in the waveform or in the spectral frequency display.

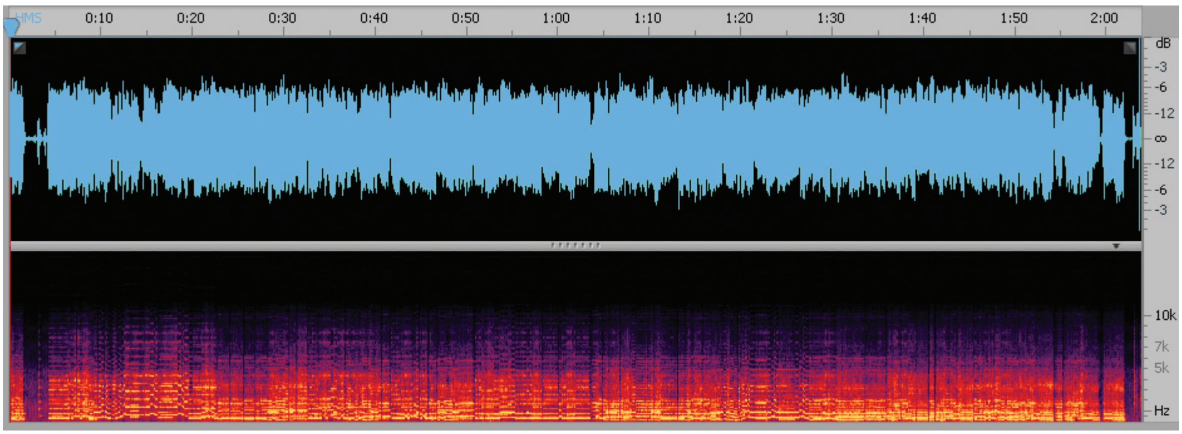
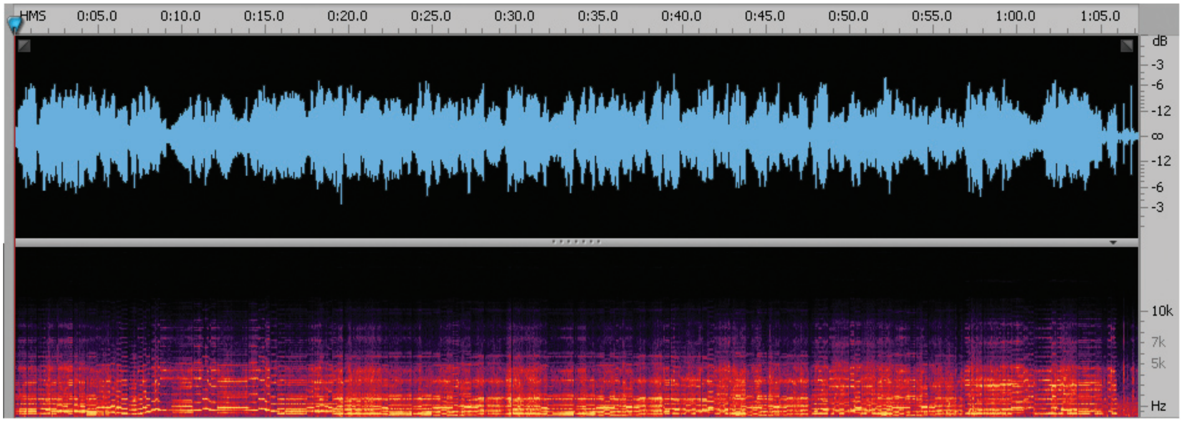


Fig. B4 (Top): waveform and SFD for control fiddle recording taken in the soundbooth at Hale Library.

Site 1 - "1 to 2 sides"

The background noise waveform shows spikes in dB due to increases in wind speed. This is would be similar to the Castle Creek Campus in that there are slopes with very little vegetation allowing stronger wind gusts to blow through the space. Birds also caused very small spikes, but very rarely due to the lack of significant vegetation nearby.



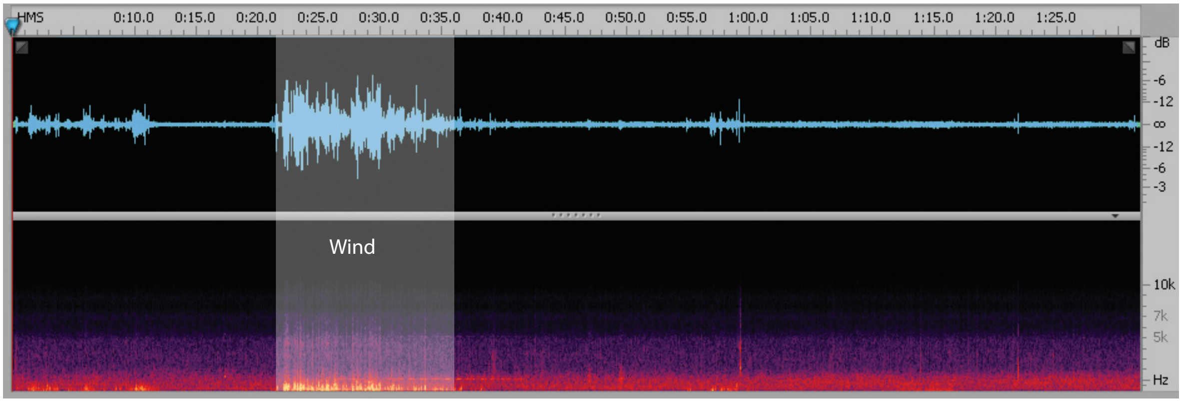
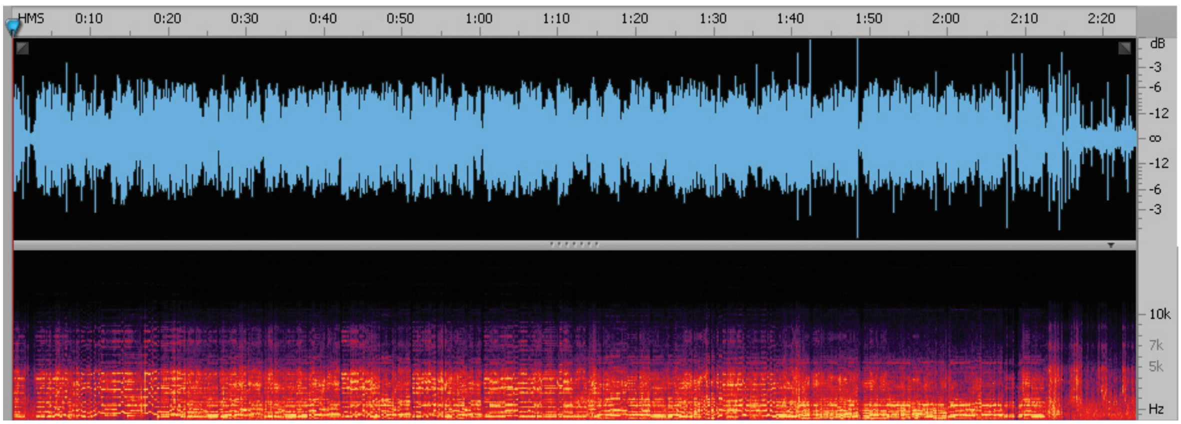


Fig. B5 (Top): waveform and SFD for fiddle recording at Site 1-"1 to 2 sides"

Fig. B6: waveform and SFD for background sound recording at Site 1-"1 to 2 sides"

Site 2 - "Materials"

Comparatively, this variable created slightly more background noise due to the concrete wall. The sound of cars at the drop-off reflected off of the wall and back into the audio recorder. Again, the spikes were created primarily by wind as well as a small group of students passing by. In general, however, this variable did not significantly deter from the intended sound of the fiddle. The movements of the musical notes are still visible in the waveform of the fiddle.



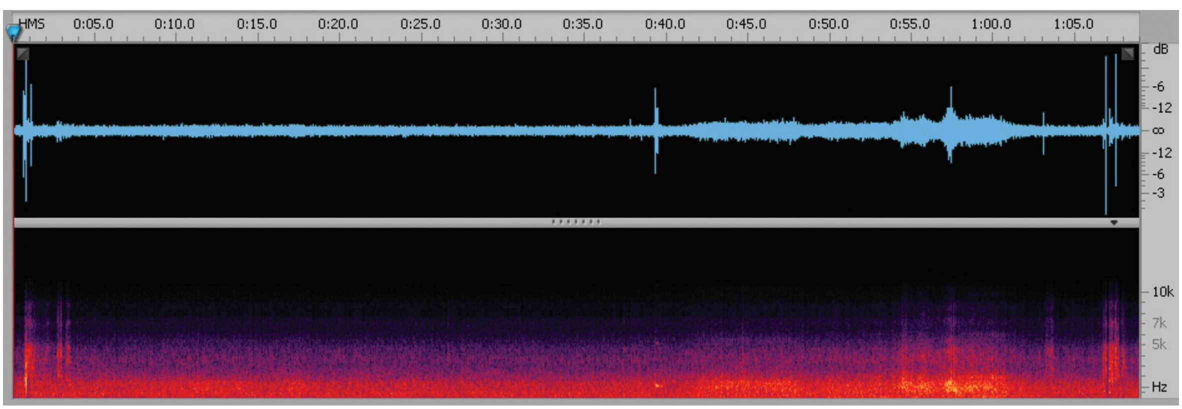


Fig. B7 (Top): waveform and SFD for fiddle recording at Site 2-"materials"

Fig. B8: waveform and SFD for background sound recording at Site 2-"materials"

Site 2 - "Rushing Water"

This variable proved to be very detrimental to the clarity of the fiddle. The fountain overbears the variations in the fiddle playing. There is a consistent rushing noise which is visible in that the waveform and SFD appear almost as one solid formation. The yellow, oranges and reds don't vary in height which indicate the loudness and softness of the fiddle. When the site was visited again to record just the background noise the fountain was shut off, but it is apparent that the fountain contributes at least -4dB levels to the recording.

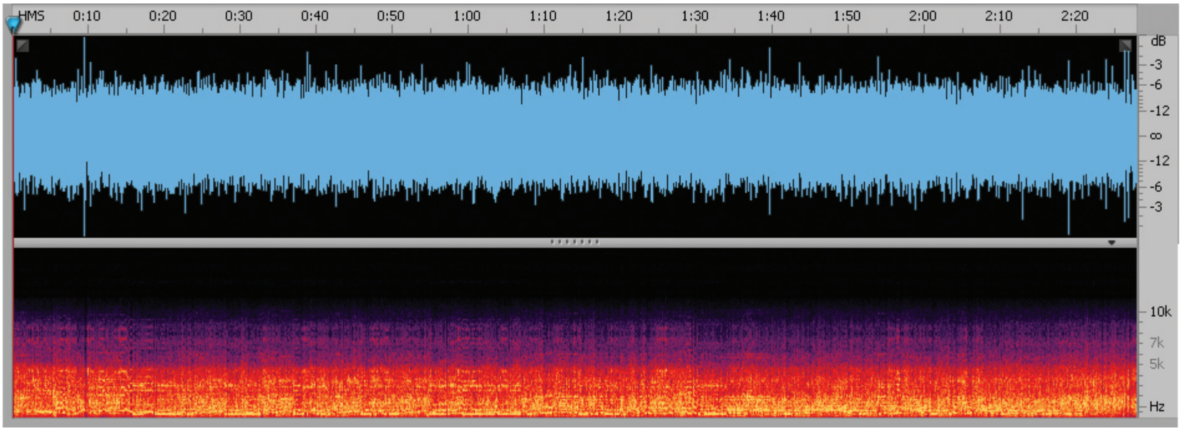
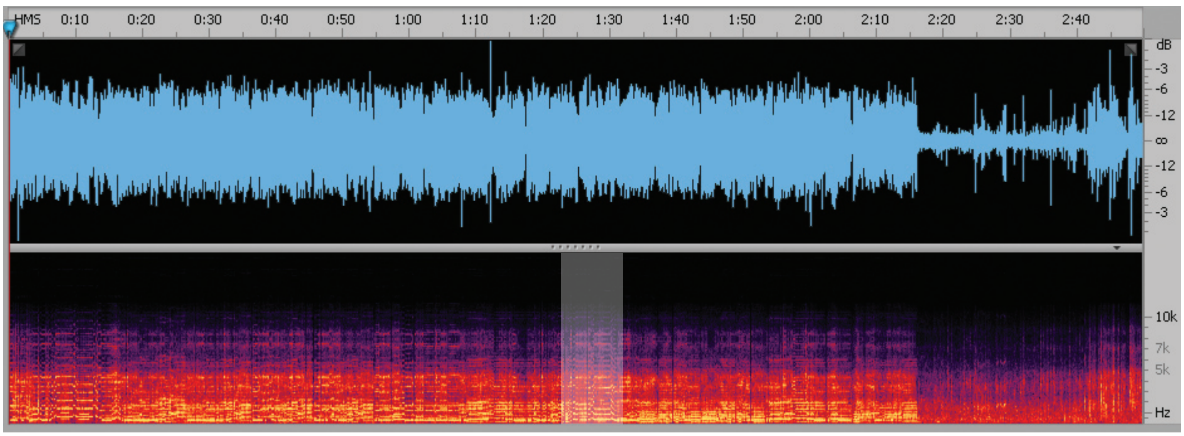


Fig. B9: waveform and SFD for fiddle recording at Site 2-"rushing water"

Site 2 - "Hard" and "0 sides"

Bosco Plaza was surprisingly calm. The only human voices recorded is shown by the small group of peaks at the 2 to 10 second mark of the background noise recording. The SFD of the fiddle recording shows the fluctuations in tone through clear ups and downs and solidity of the graduated yellows, oranges, and reds. It should be noted that in the fiddle recording the last 35 seconds are just background noise and shuffling of papers, there is no fiddle playing during this time.



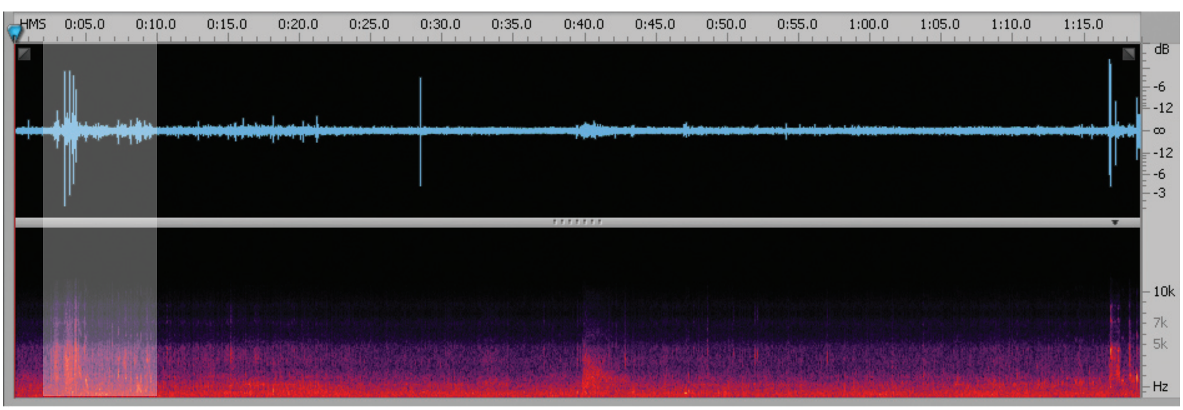
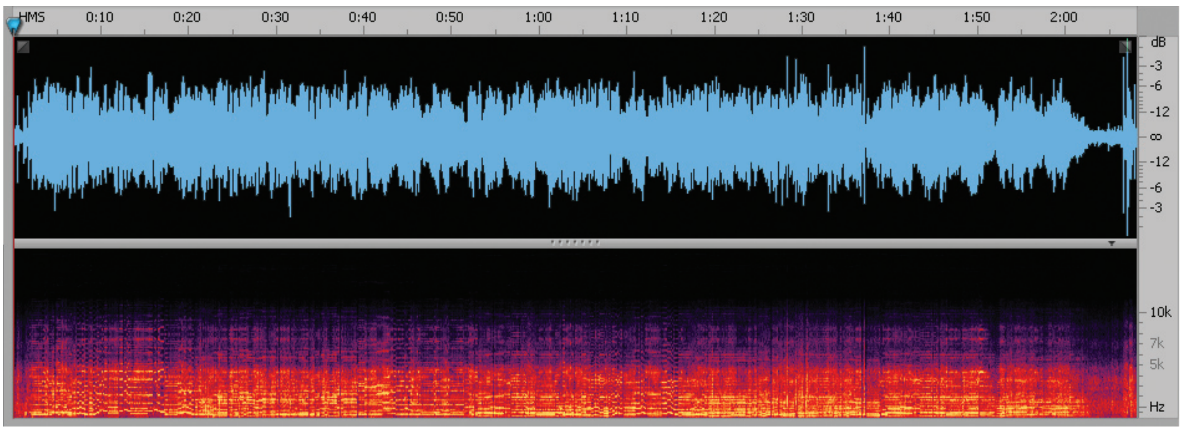


Fig. B10 (Top): waveform and SFD for fiddle recording at Site 2-"hard" and "0 sides"

Fig. B11 : waveform and SFD for background sound recording at Site 2-"hard" and "0 sides"

Site3 - "Soft" and "0 sides"

There is very little background noise interacting with the the intended sound of the fiddle. The waveform shows the musical movement of the fiddle and has very few loud noise interruptions. This result is surprising because there was construction occurring just across the street at the time.



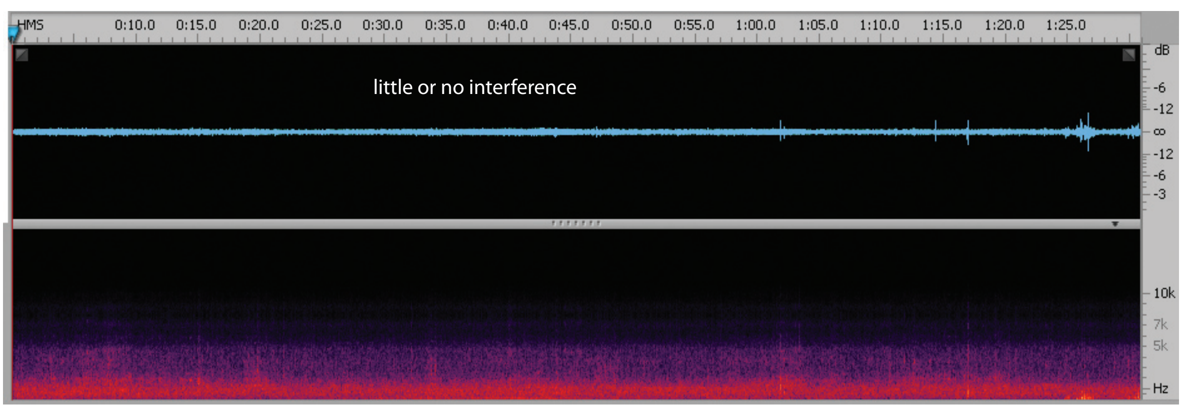
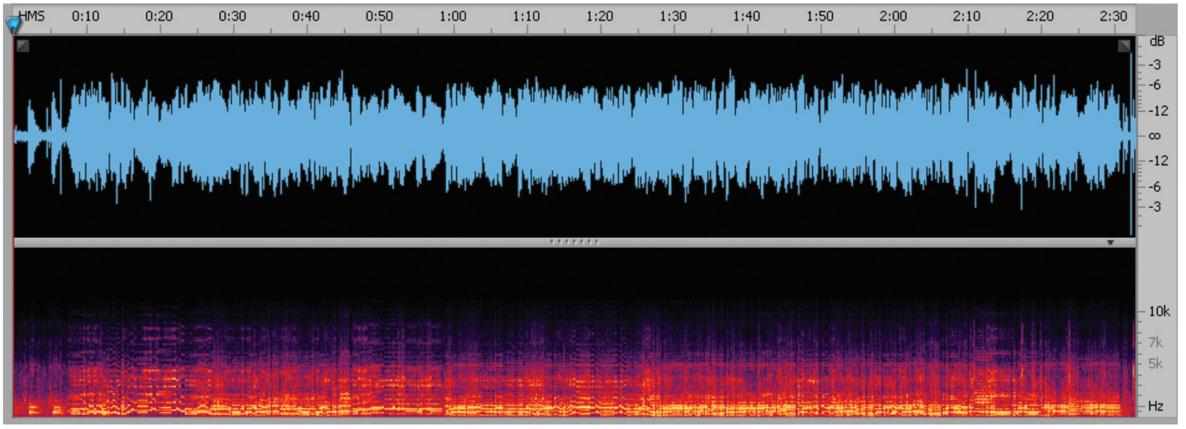


Fig. B12 (Top): waveform and SFD for fiddle recording at Site 3-"soft surface" and "0 sides"

Fig. B13: waveform and SFD for background sound recording at Site 3-"soft surface" and "0 sides"

Site 4 - "High" and "Open"

This site was also unexpectedly quiet. There were only a few birds in the space that had what appeared to be ideal bird habitats. The clarity of the fiddle in this space was quite good. The movement in the waveform is visible without spikes in the decibel level. It contains a range of crescendos due to the semi-enclosed feeling of the space.



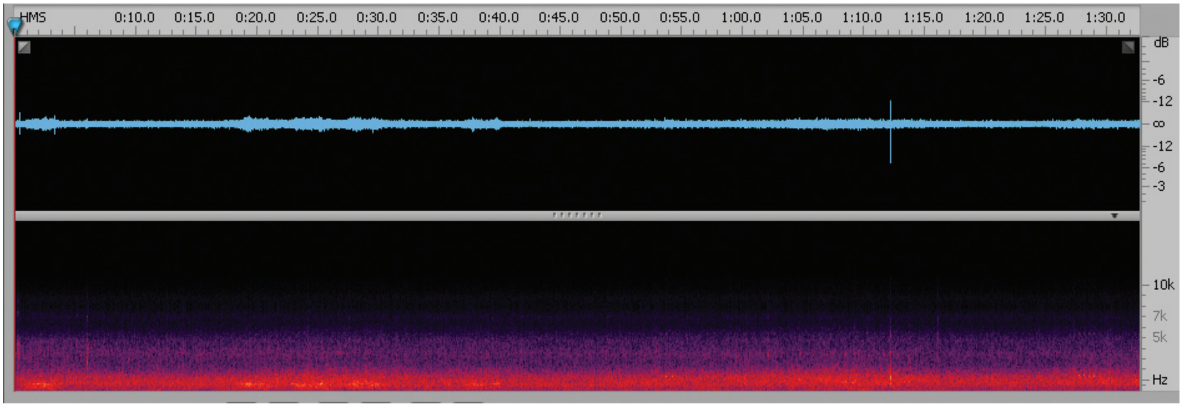


Fig. B14 (Top): waveform and SFD for fiddle recording at Site 4-"high" and "open"

Fig. B15: waveform and SFD for background sound recording at Site 4-"high" and "open canopy"

Site 5 - "Low Canopy"

The fiddle waveform for this variable is really only valid for half of the recording. The second half is just Christie plucking every once in a while. Most of the background noise here is dead leaves and limbs on the ground from the willow tree which create some absorption for the intended sound (as a good things) but also create a crunching noise (as a bad thing) interfering with the intended sound.

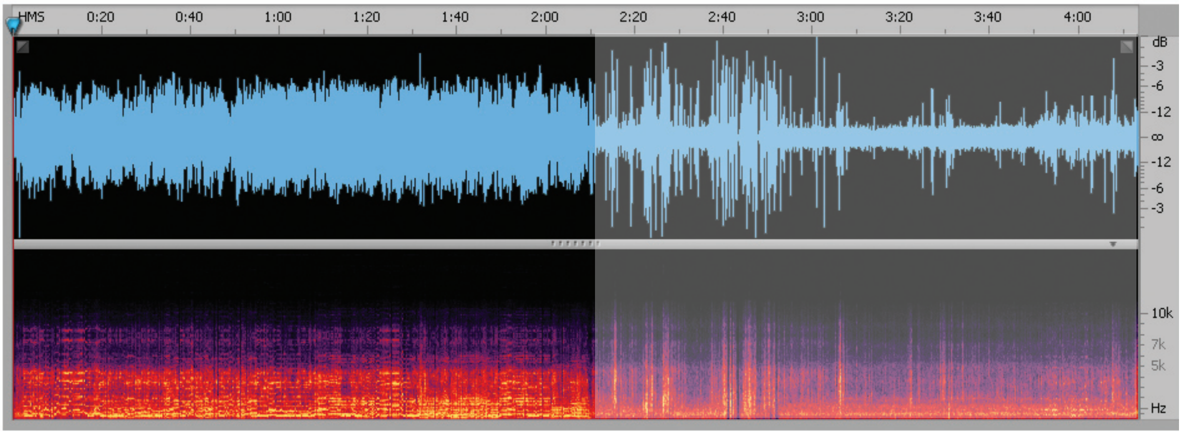
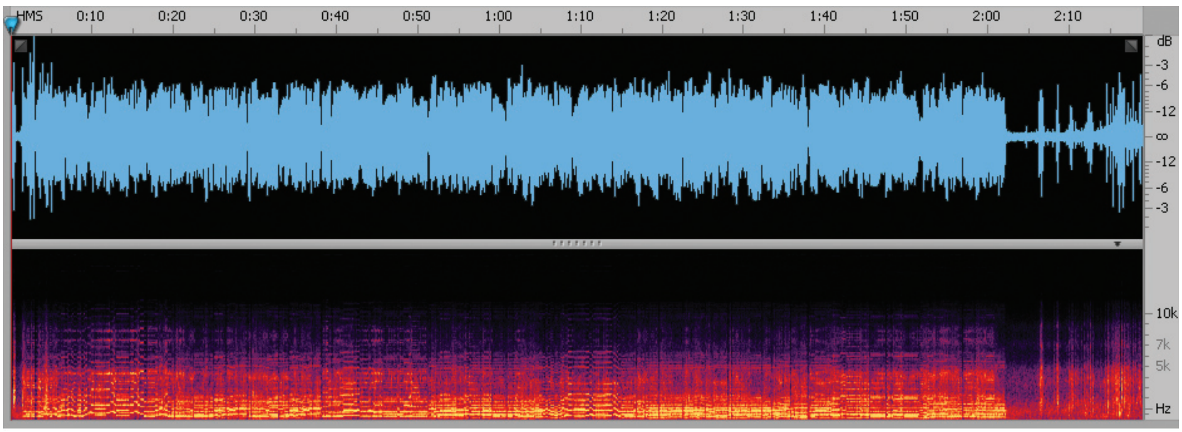


Fig. B16: waveform and SFD for fiddle recording at Site 5-"low canopy"

Site 5 - "Dense Canopy" and "Low Canopy"

The waveform here is very legible. The range of crescendo is apparent for the intended sound. There are a few spikes at the beginning and end due to the shuffling of papers and moving to turn on/off the recorder, but otherwise the recording is quite good. In the background recording there are some spikes due to birds in the honeysuckle, but that is to be expected. This type of space would be very appropriate for the intimate practice areas.



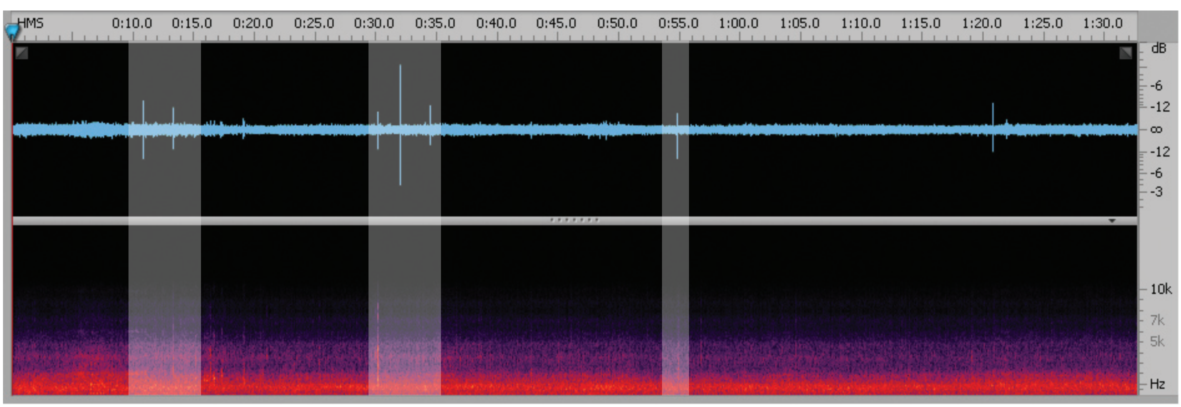
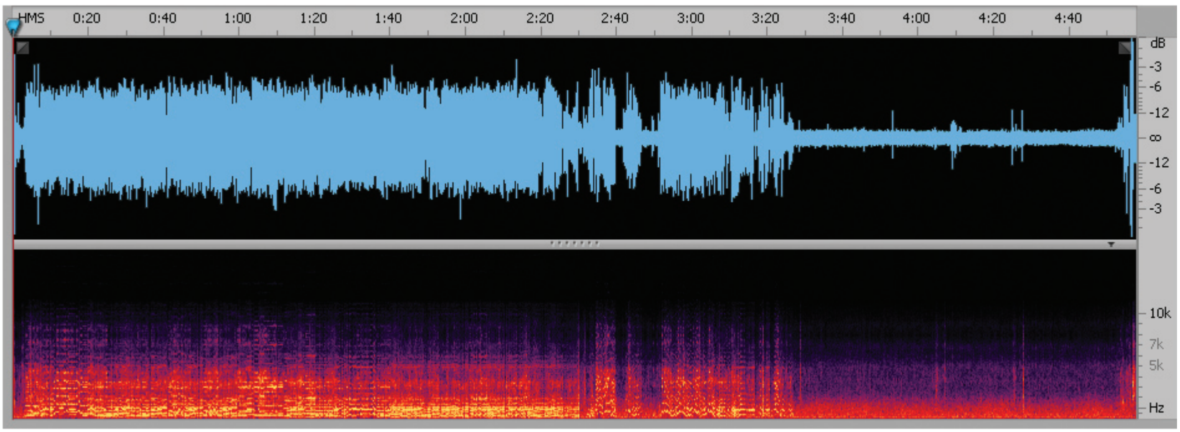


Fig. B17 (Top): Waveform and SFD for fiddle recording at Site 5-"dense canopy" and "low canopy"

Fig. B18: waveform and SFD for background sound recording at Site 5-"dense canopy" and "low canopy"

Site 6 - "4 sides"

This is another example of quality acoustics. The resonance of this site as apparent the moment one enters the space. Christie even commented "wow the acoustics in here are really good." The complete enclosure made up of hard materials made for multiple reflective surfaces which helped to diffuse the sound which according to Frederick White is important to successful acoustics because the music literally "fills the hall."



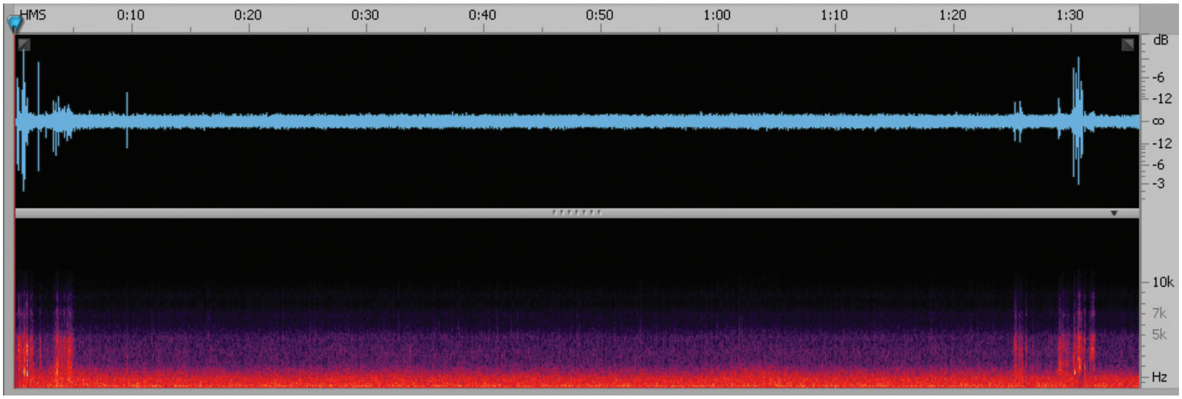


Fig. B19 (Top): waveform and SFD for fiddle recording at Site 6-"4 sides"

Fig. B20: waveform and SFD for background sound recording at Site 6 - "4 sides"

Quantitative Classification of Variables

The following classification of the variables is based on the recordings' visual interference shown in the waveforms and spectral frequency displays. This includes the amount of noise interference as well as clarity of the intended sound.

In order to place the proposed program spaces the variables need to be classified into one of four categories "excellent", "good", "fair" and "poor." Only variables with a "good" or "excellent" rating will be considered for the primary outdoor performance space. Some variables which are classified as being "fair" may be considered for small practice spaces spread throughout the campus.

Excellent

- Tack 6 Site 3 - "soft surface and 0 sides"
- Track 10 Site 6 - "4 sides"

Good

- Track 2 Site 1 - "1 to 2 sides"
- Track 3 Site 2 - "materials"
- Track 7 Site 4 - "high and open canopy"
- Track 9 Site 5 - "dense and low canopy"

Fair

- Track 5 Site 2 - "hard surface and 0 sides"
- Track 8 Site 5 - "low canopy"

Poor

- Track 4 Site 2 - "rushing water"

Qualitative Analysis of Variables

" Can musical listeners be expected to agree on what constitutes good acoustics? Are there 'goo' and 'bad' acoustics, or is acoustics a mere matter of taste? It is hard to believe that acoustics could stand alone as the one factor in the world lacking in degrees of quality."

~Leo Beranek

In the context of this thesis and project, "good" acoustics is defined by its positive relationship to terms listed in the glossary including: reverberation, clarity, warmth, loudness, brilliance, balance, blend, texture, diffusion of sound, range of crescendo, fullness of tone and uniform loudness just to name a few. In order to analyze the acoustic quality of the variables a survey of both peers and related professionals was done. These surveys would bring trusted opinions to the analysis rather than strictly my own having already made some assumptions. The first step of the qualitative analysis was to determine who's opinions would be most useful and descriptive. The first that comes to mind is a professional musician or music professor because of their experience in focused listening and ability to critique the performances of others.

Another reliable judge of acoustic quality would be broadcasting professionals. Radio DJ's work with fading in and fading out different sounds and could recognize, perhaps in a different way than musical professionals, the acoustic quality of a recorded sound. They are more accustomed to dealing with recordings whereas musicians are used to listening to live performances.

Peer evaluation is also very important. The audiences at the Castle Creek Campus will consist of "laymen" as well as music professionals. Their opinion could also provide an interesting perspective on the measure of good acoustics.

Survey Participants:

Broadcasting Professional: Cooper Banks, disk jockey at KMBZ in Kansas City, MO

Peers:

Jeremy Anterola - Landscape Architecture student

Patti Banks - Principal and Owner of PBA Landscape Architects

Scott Capps - Landscape Architecture student

Clay Deschler - Landscape Architecture student

David Hamilton - Professional Videographer

Michael Meihaus - Landscape Architecture student

Daniel Robben - Landscape Architecture student

Amy Shaffer - Landscape Architecture student

Participant Survey

The survey that given to participants included background information on the project as well as detailed instructions expressing the purpose of the study.

The interactive PDF file sent to the participants contained the audio files for each variable embedded in the file. Each variable is its own "track" beginning with the control recording as "track 1." They are able to press the buttons to play, pause and stop the sound as well as digitally circle their classification and add comments to the file. The finished surveys would then be sent back to me to compile the opinions and place each variable in a category based on my knowledge as well as the participants'.

Project Background:

This study is meant to classify specified variables in the landscape which affect acoustic quality and clarity. The information gained through this study will be used to appropriately place and design a small outdoor performance venue seating approximately 100 people as well as multiple smaller practice spaces for one to ten musical students on the Castle Creek Campus in Aspen, Colorado for use by the Aspen Music Festival and School.

Purpose:

The purpose of this particular study is to classify each track (which represents a variable) into one of four categories; Excellent, Good, Fair or Poor. Track #1 is what is considered to be the "control" track. It was recorded in a soundbooth using a handheld audio recording device. Each subsequent track was recorded outside around the Kansas State University Campus using the same recording device. While the quality of the recordings themselves are not professional, it is the desire of the surveyor that you, the participant, compare tracks 2-10 to track 1, which is in this case considered to be "excellent."

Instructions:

Step 1: Listen to track 1 and take note of the clarity of the fiddle, this is the best possible acoustic environment using this equipment, so keep this in mind for later tracks.

Step 2: Listen to next track

Step 3: Circle which classification each track falls under in YOUR opinion in terms of the clarity of the fiddle.
Excellent - clarity of fiddle is equal or very close to that of Track 1.
Good - clarity of the fiddle is slightly less than that of Track 1.
Fair - the sound of the fiddle is reasonably clear
Poor - the sound of the fiddle is very distorted

Step 4: Add any comments you may have about the track.

Step 5: Repeat steps 2-4 for each track. *Before listening to the next track, if necessary, listen again to track 1 to remind yourself what you are measuring against.

Track 2: Play Pause Stop

(circle one) Excellent Good Fair Poor

Additional Comments:

Fig. B21: example of the survey file layout (see appendix b for full document)

Study Responses

	Excellent	Good	Fair	Poor	Additional Comments
Track 1 - Control	**X**				
Track 2 - Site 1 " 1 to 2 sides"	**X**				
Cooper Banks		X			
Jeremy Anterola	X				Very mellow, relaxed, calming
Patricia Banks	X				
Robin Banks	X				
Scott Capps	X				very clear, the same if not better than the first
Clay Deschler	X				
Dave Hamilton		X			
Michael Meihaus			X		
Dan Robben		X			
Amy Shaffer	X				
Track 3 - Site 2 "Materials"		**X**			
Cooper Banks			X		
Jeremy Anterola		X			A bit brisker, sounds as if there are passing ambient noises, steps perhaps?
Patricia Banks		X			
Robin Banks		X			
Scott Capps		X			could hear wind in background, especially at beginning of track
Clay Deschler		X			
Dave Hamilton			X		
Michael Meihaus			X		
Dan Robben			X		
Amy Shaffer			X		
Track 4 - Site 2 "Rushing Water"				**X**	
Cooper Banks				X	
Jeremy Anterola				X	Heavy traffic? Lots of static, hard to distinguish
Patricia Banks				X	
Robin Banks				X	
Scott Capps				X	close to water? music definitely had to compete with the background noise
Clay Deschler				X	
Dave Hamilton				X	
Michael Meihaus				X	ambient sounds are nice... but are too close and take away from the quality of the fiddle.
Dan Robben				X	
Amy Shaffer				X	

	Excellent	Good	Fair	Poor	Additional Comments
Track 5 - Site 2 "Hard & 0 sides"			**X**		
Cooper Banks			X		
Jeremy Anterola		X			At the same level as original (very loud) but clarity can be lost with some background clutter/noise
Patricia Banks		X			
Robin Banks			X		
Scott Capps			X		a little static-y; people in background?
Clay Deschler			X		
Dave Hamilton			X		
Michael Meihaus	X				Best so far.
Dan Robben		X			
Amy Shaffer		X			
Track 6 - Site 3 "Soft & 0sides"		**X**			
Cooper Banks		X			
Jeremy Anterola		X			Same as previous, though a little bit more static
Patricia Banks		X			
Robin Banks	X				
Scott Capps		X			burst of static hear and there...
Clay Deschler	X				
Dave Hamilton		X			
Michael Meihaus		X			
Dan Robben	X				
Amy Shaffer			X		
Track 7 - Site 4 "High & Open"		**X**			
Cooper Banks			X		
Jeremy Anterola		X			Definitely can tell it is on campus with the bell sounds (I think this helps to point out WHERE you could potentially be - closer or further from campus and dependent on time of day, really cool too to consider this as an auditory especially if you hadn't realized it though I'm sure you did)
Patricia Banks		X			
Robin Banks		X			
Scott Capps	X				aside from the bell at the beginning, the quality seemed great
Clay Deschler		X			
Dave Hamilton		X			
Michael Meihaus		X			Sounds more distant or dispersed, but good.
Dan Robben	X				
Amy Shaffer		X			

	Excellent	Good	Fair	Poor	Additional Comments
Track 8 - Site 5 "Low"			**X**		
Cooper Banks				X	
Jeremy Anterola			X		
Patricia Banks			X		
Robin Banks			X		
Scott Capps		X			a little windy?
Clay Deschler			X		
Dave Hamilton			X		
Michael Meihaus			X		distracting ambient noise.
Dan Robben				X	
Amy Shaffer				X	
Track 9 - Site 5 "Low & Dense"		**X**			
Cooper Banks			X		
Jeremy Anterola		X			
Patricia Banks			X		
Robin Banks		X			
Scott Capps	X				parts were extremely clear, beter than the first..
Clay Deschler				X	
Dave Hamilton			X		
Michael Meihaus	X				sounds almost indoor quality except for mild ambient noise.
Dan Robben			X		
Amy Shaffer		X			
Track 10 - Site 6 "4 sides"			**X**		
Cooper Banks		X			
Jeremy Anterola			X		Tone seems hollow as if within a space, course I could be completely off
Patricia Banks		X			
Robin Banks	X				
Scott Capps			X		a little static-y
Clay Deschler			X		
Dave Hamilton			X		
Michael Meihaus			X		does not stand out compared to others.
Dan Robben			X		
Amy Shaffer			X		

Overall Variable Classification

As visible when comparing the resulting classifications of the quantitative and qualitative analyses both produced different, but similar results. Much of the classifications were no more than one category off. For instance, in the quantitative analysis Track 6 (Site 3 - "Soft and 0 Sides") was classified as "excellent," but in the qualitative analysis is was considered "good." The only exception is Track 10 (Site 6 - "4 sides"). It dropped from "excellent" to "fair." It is believed that this is due to the portion of the recording participants listened to. Before taking the survey, participants were told that they did not need to listen to the entire recording, just a couple of minutes. On this particular track in the first minute there is a particular note Christie plays that causes the recording to get fuzzy. This is likely due to the quality limitations of the recording equipment and not a result of the space's acoustics, but should still be taken into consideration. The following classifications are based on the culmination of both qualitative and quantitative analysis.

Excellent

- Track 2 Site 1 - "1 to 2 sides"

Good

- Track 3 Site 2 - "materials"
- Track 6 Site 3 - "soft surface and 0 sides"
- Track 7 Site 4 - "high and open canopy"
- Track 9 Site 5 - "dense and low canopy"
- Track 10 Site 6 - "4 sides"

Fair

- Track 5 Site 2 - "hard surface and 0 sides"
- Track 8 Site 5 - "low canopy"

Poor

- Track 4 Site 2 - "rushing water"

data sheets for each “site”

"2 Sides"

Site: #1 - Old ~~Museum~~ Stadium

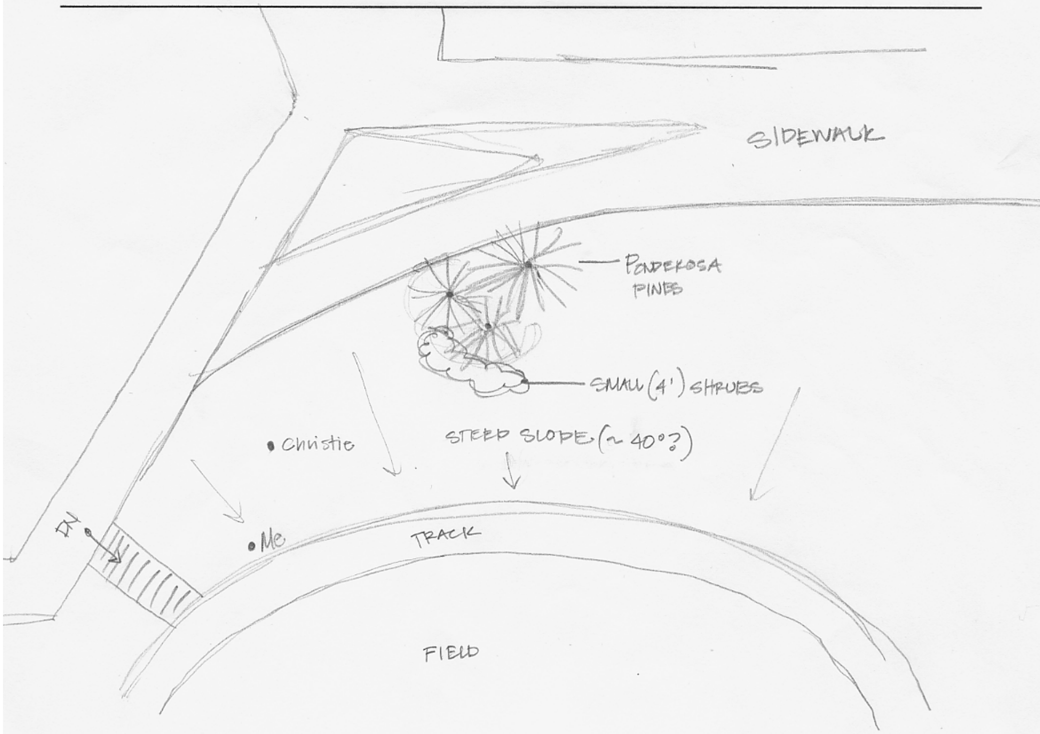
Weather Conditions: Sunny
lt. breeze
56°F

Time: 11:39
Date: 10·28·08
Description:

Vegetation - some small shrubs
large pines approx. 20' away from source
groundcover almost entirely turf grass on steep slope.

Wildlife - crickets (5-10)

Materials - turf, crunchy...



"Hard"

Site: #2 Bosco Plaza - Hard/Qsides

Weather Conditions: sunny
lt. breeze
58°F

Time: 11:50

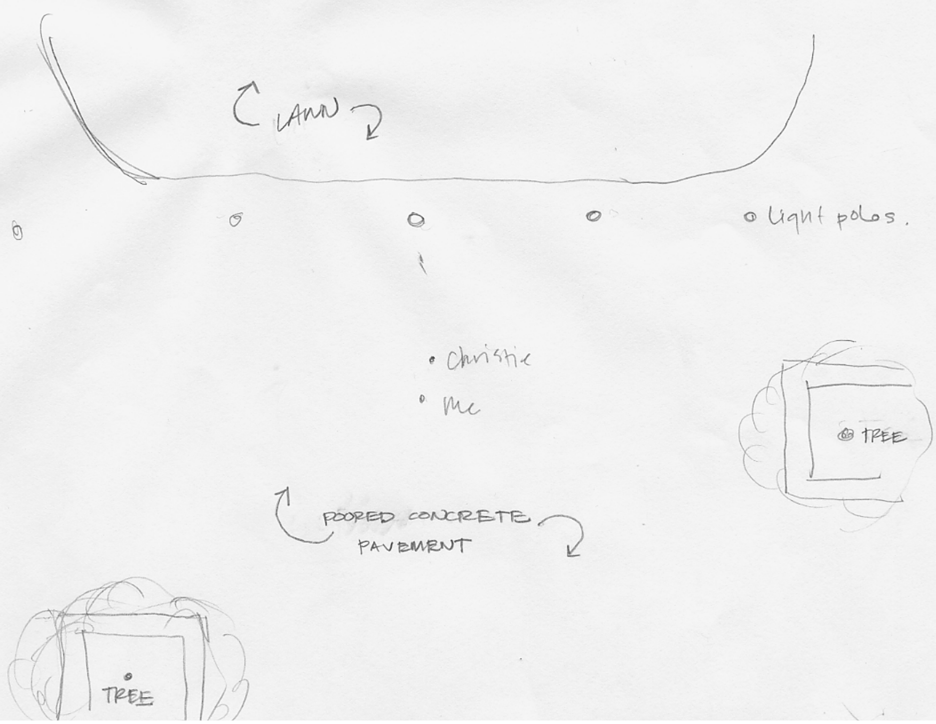
Date: 10.28.08

Description: open plaza

Vegetation -

Wildlife -

Materials - conc. panels onground.
20' from open lawn area.



"~~Time of Day~~"

Site: #2 Bosco - Materials

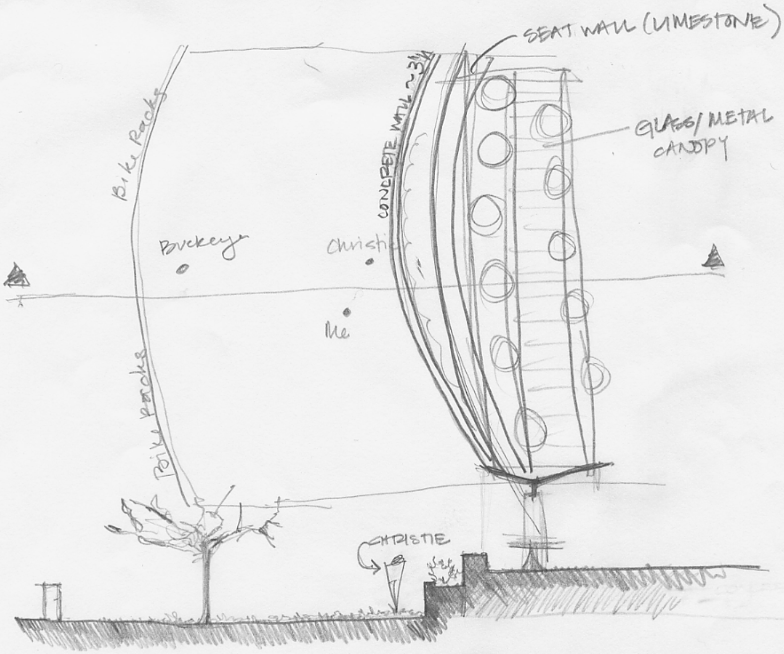
Weather Conditions: sunny
lt breeze
56°F

Time: 11:42
Date: 10.27.08
Description: turf grass 3' from conc. wall w/ tiered arborvitae evergreen veg.

Vegetation - turf; Eq shrubs
1 small tree

Wildlife - crickets (1)

Materials - conc. limestone



Site: #2 Bosco Plaza - Rushing Water.

Time: 12:46

Date: 10·28·08

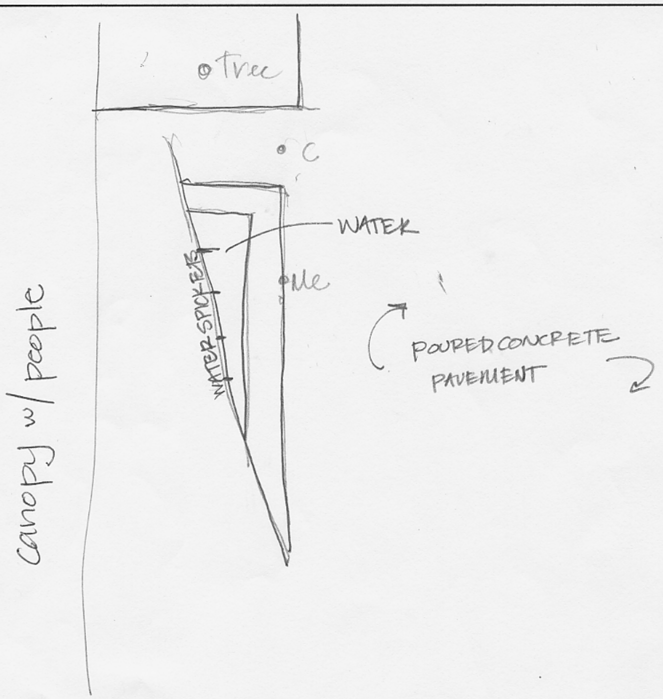
Description: Bosco Plaza near fountain

Weather Conditions: sunny
lt. breeze
60° F

Vegetation - Small tree (15-20'h) speratic low ground cover (3-6")

Wildlife - none, but about 20 people under canopy @tables

Materials - concrete, water, some soft, but not prodominant



"Soft" ? "2 sides"

Site: #3 Anderson Lawn

Weather Conditions: sunny
light breeze
59°F

Time: 11:57 a.m.
Date: 10.27.08
Description: Open field

Vegetation - turf grass
large trees over 100' away

Wildlife - none nearby

Materials - all natural, but construction going on within hearing distance

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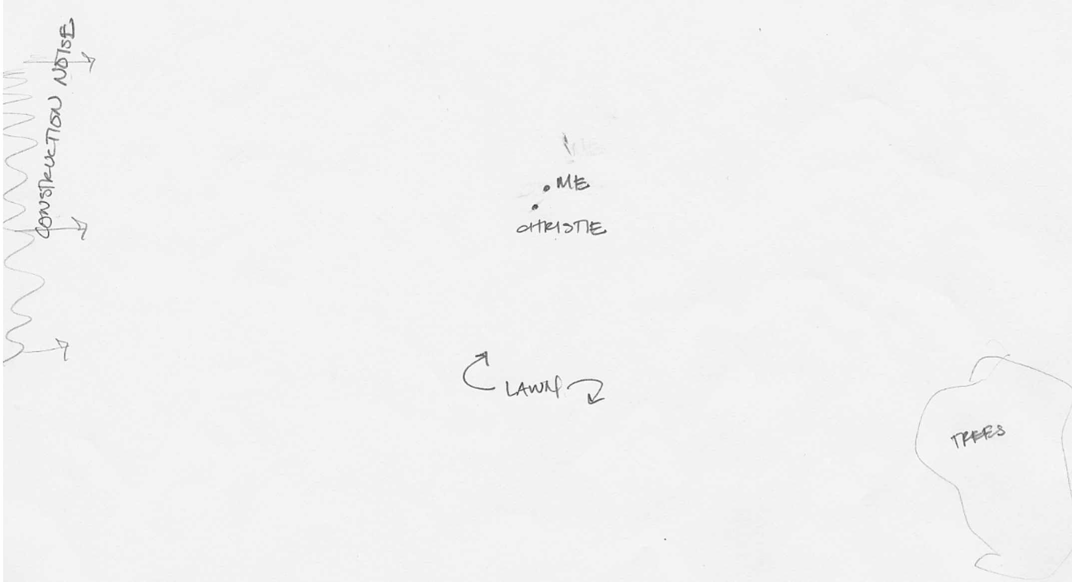


"High canopy" : open canopy

Site: #4 E. of President's House

Time: mid-day

Date: 10.28.08

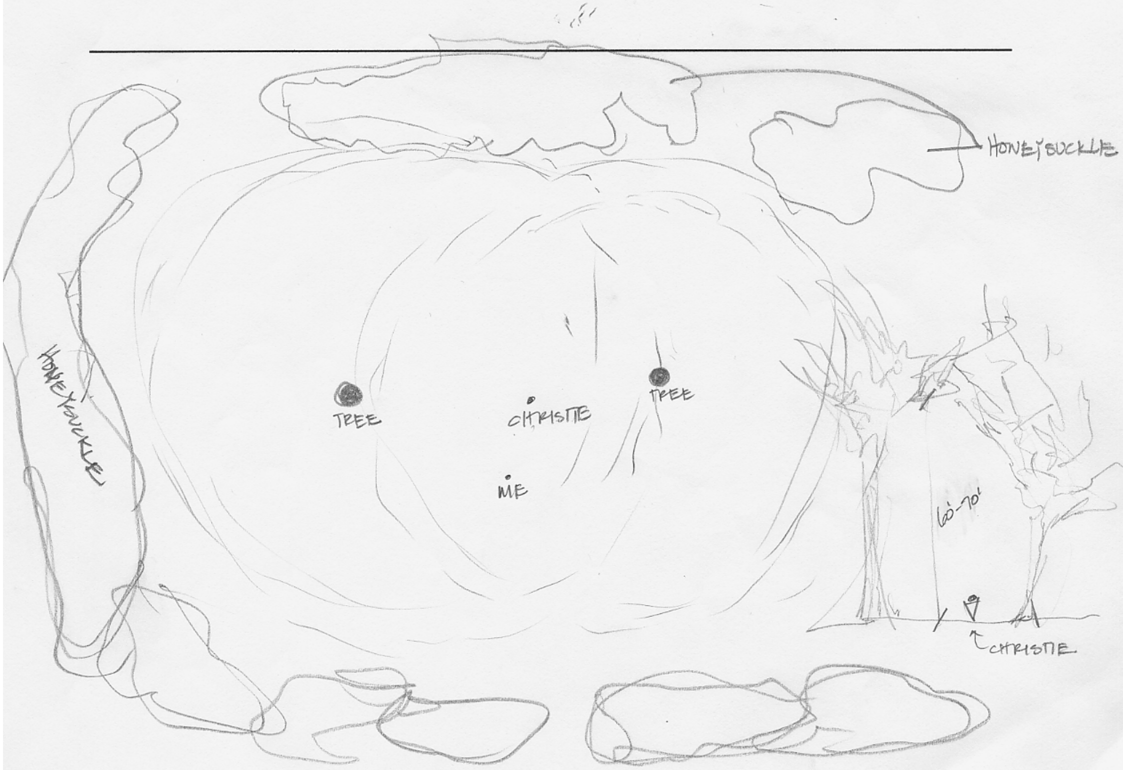
Description:

Weather Conditions: sunny
wind slight - 5 mph.
59° F

Vegetation - high canopy open trees. Approx. 60-70' high.
small (6-10') shrubs - I think honeysuckle

Wildlife - some crickets
2-5 birds in the trees

Materials - surrounding materials are natural
very diverse groundcover, lots of dead leaves : broken limbs



"Dense"

Site: #5 S. of ISS

Weather Conditions: sunny
lt. breeze
~~58~~ °F
60

Time: 12:09
Date: 10·28·08
Description:

Vegetation - surrounded by large honeysuckles approx. 12' high

Wildlife - squirrell, crickets 1 or 2 birds

Materials - all natural

"low" - Dense canopy

Site: #5 E. of 155

Weather Conditions: sunny
lt. breeze
60°F

Time: 12:15

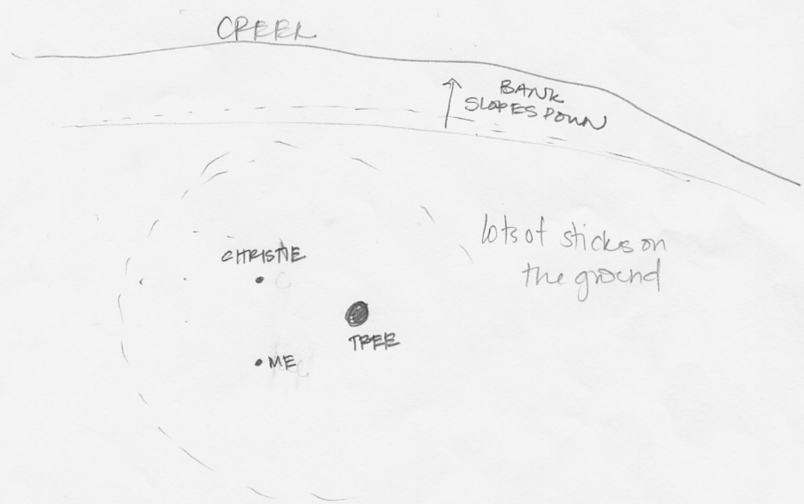
Date:

Description: low willow 15' F

Vegetation - willow tree

Wildlife - a few crickets
2 birds. (in the willow tree)

Materials - ~~cat~~ all soft scape
dead limbs/leaves on ground.



"4 sides"

Site: #6 Webber Hall Courtyard

Weather Conditions: sunny
H. breeze
60°F

Time: 12:30

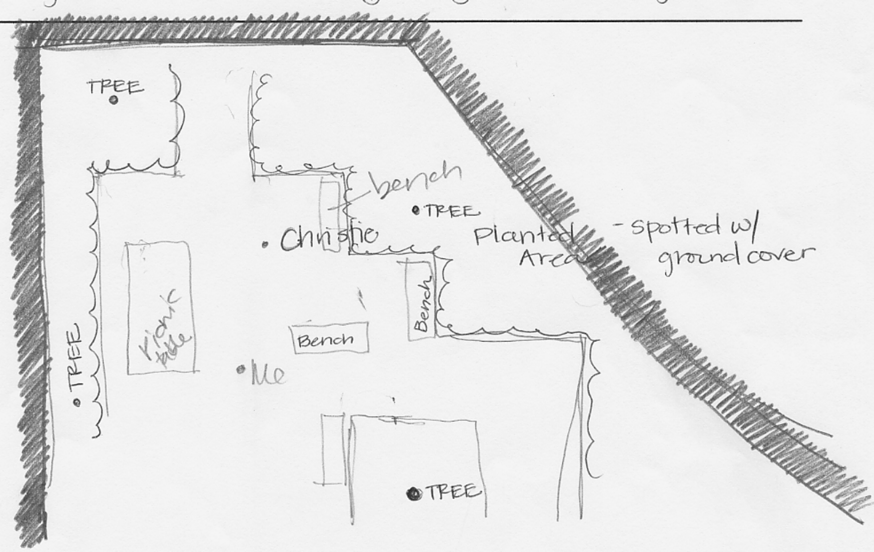
Date:

Description: courtyard

Vegetation - generally open canopy on all
a few small trees - ~~[illegible]~~ 12 - 25' height
low ground cover . 2-6"

Wildlife - 2-3 birds . chirping

Materials - picnic tables - wooden
wooden benches
concrete sidewalk
glass windows on each story facing into the courtyard



comparative sound study

Project Background:

This study is meant to classify specified variables in the landscape which affect acoustic quality and clarity. The information gained through this study will be used to appropriately place and design a small outdoor performance venue seating approximately 100 people as well as multiple smaller practice spaces for one to ten musical students on the Castle Creek Campus in Aspen, Colorado for use by the Aspen Music Festival and School.

Purpose:

The purpose of this particular study is to classify each track (which represents a variable) into one of four categories; Excellent, Good, Fair or Poor. Track #1 is what is considered to be the "control" track. It was recorded in a soundbooth using a handheld audio recording device. Each subsequent track was recorded outside around the Kansas State University Campus using the same recording device. While the quality of the recordings themselves are not professional, it is the desire of the surveyor that you, the participant, compare tracks 2-10 to track 1, which is in this case considered to be "excellent."

Instructions:

Step 1: Listen to track 1 and take note of the clarity of the fiddle, this is the best possible acoustic environment using this equipment, so keep this in mind for later tracks.

Step 2: Listen to next track

Step 3: Circle which classification each track falls under in YOUR opinion in terms of the clarity of the fiddle.
Excellent - clarity of fiddle is equal or very close to that of Track 1.
Good - clarity of the fiddle is slightly less than that of Track 1.
Fair - the sound of the fiddle is reasonably clear
Poor - the sound of the fiddle is very distorted

Step 4: Add any comments you may have about the track.

Step 5: Repeat steps 2-4 for each track. *Before listening to the next track, if necessary, listen again to track 1 to remind yourself what you are measuring against.

Track 1: Control

(check one) Excellent Good Fair Poor

Additional Comments:

Track 2:

(check one) Excellent Good Fair Poor

Additional Comments:

Track 3:

(check one) Excellent Good Fair Poor

Additional Comments:

Track 4:

(check one) Excellent Good Fair Poor

Additional Comments:

Track 5:

(check one) Excellent Good Fair Poor

Additional Comments:

Track 6:

(check one) Excellent Good Fair Poor

Additional Comments:

Track 7:

(check one) Excellent Good Fair Poor

Additional Comments:

Track 8:

(check one) Excellent Good Fair Poor

Additional Comments:

Track 9:

(check one) Excellent Good Fair Poor

Additional Comments:

Track 10:

(check one) Excellent Good Fair Poor

Additional Comments:

qualitative survey responses

jeremy anterola

Track 1: Control http://capd.ksu.edu/media/audio/Track1.wav
(presumed to be classified as "excellent")
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

Track 2: http://capd.ksu.edu/media/audio/Track2.wav
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments: Very mellow, relaxed, calming

Track 3: http://capd.ksu.edu/media/audio/Track3.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments: A bit brisker, sounds as if there are passing ambient noises, steps perhaps?

Track 4: http://capd.ksu.edu/media/audio/Track4.wav
(check one) Excellent[] Good[] Fair[] Poor[x]
Additional Comments: Heavy traffic? Lots of static, hard to distinguish the noise

Track 5: http://capd.ksu.edu/media/audio/Track5.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments: At the same level as original (very loud) but clarity can be lost with some background clutter/noise

Track 6: http://capd.ksu.edu/media/audio/Track6.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments: Same as previous, though a little bit more static

Track 7: http://capd.ksu.edu/media/audio/Track7.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments: Definitely can tell it is on campus with the bell sounds (I think this helps to point out WHERE you could potentially be - closer or further from campus and dependent on time of day, really cool too to consider this as an auditory especially if you hadn't realized it though I'm sure you did)

Track 8: http://capd.ksu.edu/media/audio/Track8.wav
(check one) Excellent[] Good[] Fair[X] Poor[]
Additional Comments:

Track 9: http://capd.ksu.edu/media/audio/Track9.wav
(check one) Excellent[] Good[X] Fair[] Poor[]
Additional Comments:

Track 10: http://capd.ksu.edu/media/audio/Track10.wav
(check one) Excellent[] Good[] Fair[X] Poor[]
Additional Comments: Tone seems hollow as if within a space, course I could be completely off

patti banks

Track 1: Control http://capd.ksu.edu/media/audio/Track1.wav
(presumed to be classified as "excellent")
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

Track 2: http://capd.ksu.edu/media/audio/Track2.wav
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

Track 3: http://capd.ksu.edu/media/audio/Track3.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 4: http://capd.ksu.edu/media/audio/Track4.wav
(check one) Excellent[] Good[] Fair[] Poor[x]
Additional Comments:

Track 5: http://capd.ksu.edu/media/audio/Track5.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 6: http://capd.ksu.edu/media/audio/Track6.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 7: http://capd.ksu.edu/media/audio/Track7.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 8: http://capd.ksu.edu/media/audio/Track8.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

Track 9: http://capd.ksu.edu/media/audio/Track9.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

Track 10: http://capd.ksu.edu/media/audio/Track10.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

robin banks (me)

Track 1: Control http://capd.ksu.edu/media/audio/Track1.wav
(presumed to be classified as "excellent")
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

Track 2: http://capd.ksu.edu/media/audio/Track2.wav
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments: very clear, almost better than the control recording

Track 3: http://capd.ksu.edu/media/audio/Track3.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 4: http://capd.ksu.edu/media/audio/Track4.wav
(check one) Excellent[] Good[] Fair[] Poor[x]
Additional Comments: rushing water makes sound of fiddle muddy

Track 5: http://capd.ksu.edu/media/audio/Track5.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

Track 6: http://capd.ksu.edu/media/audio/Track6.wav
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

Track 7: http://capd.ksu.edu/media/audio/Track7.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 8: http://capd.ksu.edu/media/audio/Track8.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

Track 9: http://capd.ksu.edu/media/audio/Track9.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 10: http://capd.ksu.edu/media/audio/Track10.wav
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

scott capps

Track 1: Control http://capd.ksu.edu/media/audio/Track1.wav
(presumed to be classified as "excellent")
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

Track 2: http://capd.ksu.edu/media/audio/Track2.wav
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments: very clear, the same if not better than the first

Track 3: http://capd.ksu.edu/media/audio/Track3.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments: could hear wind in background, especially at beginning of track

Track 4: http://capd.ksu.edu/media/audio/Track4.wav
(check one) Excellent[] Good[] Fair[] Poor[x]
Additional Comments: close to water? music definitely had to compete with the background noise

Track 5: http://capd.ksu.edu/media/audio/Track5.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments: a little static-y; people in background?

Track 6: http://capd.ksu.edu/media/audio/Track6.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments: burst of static hear and there...

Track 7: http://capd.ksu.edu/media/audio/Track7.wav
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments: aside from the bell at the beginning, the quality seemed great

Track 8: http://capd.ksu.edu/media/audio/Track8.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments: a little windy?

Track 9: http://capd.ksu.edu/media/audio/Track9.wav
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments: parts were extremely clear, beter than the first..

Track 10: http://capd.ksu.edu/media/audio/Track10.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments: a little static-y

clay deschler

Track 1: Control http://capd.ksu.edu/media/audio/Track1.wav
(presumed to be classified as "excellent")
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

Track 2: http://capd.ksu.edu/media/audio/Track2.wav
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

Track 3: http://capd.ksu.edu/media/audio/Track3.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 4: http://capd.ksu.edu/media/audio/Track4.wav
(check one) Excellent[] Good[] Fair[] Poor[x]
Additional Comments:

Track 5: http://capd.ksu.edu/media/audio/Track5.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

Track 6: http://capd.ksu.edu/media/audio/Track6.wav
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

Track 7: http://capd.ksu.edu/media/audio/Track7.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 8: http://capd.ksu.edu/media/audio/Track8.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

Track 9: http://capd.ksu.edu/media/audio/Track9.wav
(check one) Excellent[] Good[] Fair[] Poor[x]
Additional Comments:

Track 10: http://capd.ksu.edu/media/audio/Track10.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

david hamilton

Track 1: Control http://capd.ksu.edu/media/audio/Track1.wav
(presumed to be classified as "excellent")
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

Track 2: http://capd.ksu.edu/media/audio/Track2.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 3: http://capd.ksu.edu/media/audio/Track3.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

Track 4: http://capd.ksu.edu/media/audio/Track4.wav
(check one) Excellent[] Good[] Fair[] Poor[x]
Additional Comments:

Track 5: http://capd.ksu.edu/media/audio/Track5.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

Track 6: http://capd.ksu.edu/media/audio/Track6.wav
(check one) Excellent[] Good[x] Fair[] Poor[]

Additional Comments:

Track 7: http://capd.ksu.edu/media/audio/Track7.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 8: http://capd.ksu.edu/media/audio/Track8.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

Track 9: http://capd.ksu.edu/media/audio/Track9.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

Track 10: http://capd.ksu.edu/media/audio/Track10.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

mike miehaus

Track 1: Control http://capd.ksu.edu/media/audio/Track1.wav
(presumed to be classified as "excellent")
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

Track 2: http://capd.ksu.edu/media/audio/Track2.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

Track 3: http://capd.ksu.edu/media/audio/Track3.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

Track 4: http://capd.ksu.edu/media/audio/Track4.wav
(check one) Excellent[] Good[] Fair[] Poor[x]
Additional Comments: ambient sounds are nice... but are too close and take away from the quality of the fiddle.

Track 5: http://capd.ksu.edu/media/audio/Track5.wav
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments: Best so far.

Track 6: http://capd.ksu.edu/media/audio/Track6.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 7: http://capd.ksu.edu/media/audio/Track7.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments: Sounds more distant or dispersed, but good.

Track 8: http://capd.ksu.edu/media/audio/Track8.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments: distracting ambient noise.

Track 9: http://capd.ksu.edu/media/audio/Track9.wav
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments: sounds almost indoor quality except for mild ambient noise.

Track 10: http://capd.ksu.edu/media/audio/Track10.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments: does not stand out compared to others.

Track 1: Control http://capd.ksu.edu/media/audio/Track1.wav
(presumed to be classified as "excellent")
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

Track 2: http://capd.ksu.edu/media/audio/Track2.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 3: http://capd.ksu.edu/media/audio/Track3.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

Track 4: http://capd.ksu.edu/media/audio/Track4.wav
(check one) Excellent[] Good[] Fair[] Poor[x]
Additional Comments:

Track 5: http://capd.ksu.edu/media/audio/Track5.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 6: http://capd.ksu.edu/media/audio/Track6.wav
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

Track 7: http://capd.ksu.edu/media/audio/Track7.wav
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

Track 8: http://capd.ksu.edu/media/audio/Track8.wav
(check one) Excellent[] Good[] Fair[] Poor[x]
Additional Comments:

Track 9: http://capd.ksu.edu/media/audio/Track9.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

Track 10: http://capd.ksu.edu/media/audio/Track10.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

amy shaffer

Track 1: Control http://capd.ksu.edu/media/audio/Track1.wav
(presumed to be classified as "excellent")
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

Track 2: http://capd.ksu.edu/media/audio/Track2.wav
(check one) Excellent[x] Good[] Fair[] Poor[]
Additional Comments:

Track 3: http://capd.ksu.edu/media/audio/Track3.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

Track 4: http://capd.ksu.edu/media/audio/Track4.wav
(check one) Excellent[] Good[] Fair[] Poor[x]
Additional Comments:

Track 5: http://capd.ksu.edu/media/audio/Track5.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 6: http://capd.ksu.edu/media/audio/Track6.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

Track 7: http://capd.ksu.edu/media/audio/Track7.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 8: http://capd.ksu.edu/media/audio/Track8.wav
(check one) Excellent[] Good[] Fair[] Poor[x]
Additional Comments:

Track 9: http://capd.ksu.edu/media/audio/Track9.wav
(check one) Excellent[] Good[x] Fair[] Poor[]
Additional Comments:

Track 10: http://capd.ksu.edu/media/audio/Track10.wav
(check one) Excellent[] Good[] Fair[x] Poor[]
Additional Comments:

appendix c - design details information

metal fabric

GKDMETALFABRICS

GKD-USA Inc
825 Chesapeake Drive
Cambridge MD 21613

T 800 453 8616
T 410 221 0542
F 410 221 0544
gkdmetalfabrics.com

Escale 7x1

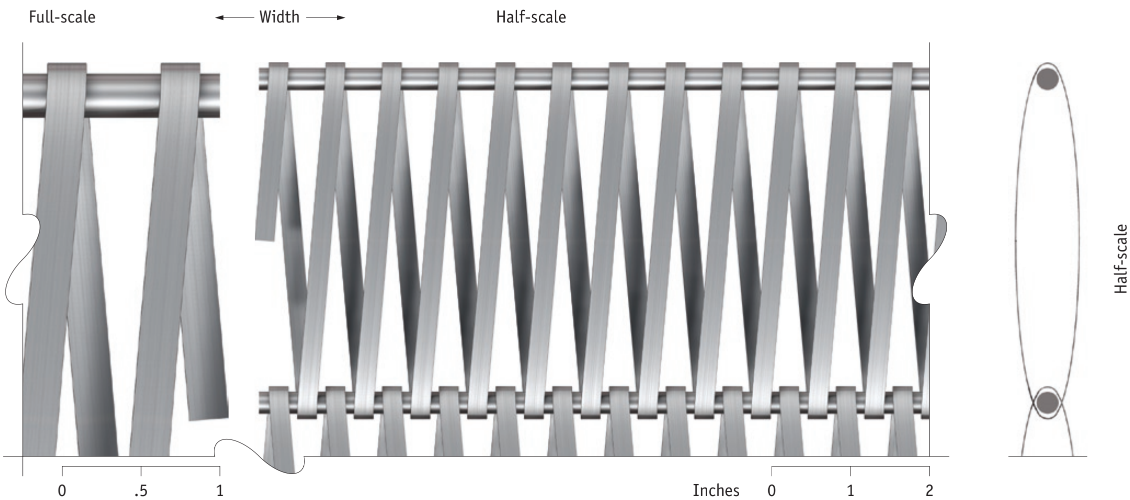
Flexible, one direction

Material	AISI Type 316 stainless steel
Open area	50%
Weight	1.85 lbs/sqft
Thickness	0.87"
Rod	0.28" diameter
Flat strip	0.28" wide, 0.04" thick
Opening	3.75" x 0.55"

Escale is available in a range of sizes. Please consult GKD Engineering for further assistance.

Product specifications are subject to change. All measurements are approximate and should be confirmed with a sample.

Attachment methods
Woven-in bar with spring
Eyebolt



PDF/0105

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F 410 221 0544
gkdmetalfabrics.com

Woven-in bar with spring

This system was developed specifically for façades and parking structures where tension loads require consideration. Round bars are inserted into the fabric in place of weft wires at the top, bottom and intermediate locations. The top round bar is inserted into triangular brackets. Any intermediate round bars are connected to pivoting brackets for lateral support. Springs attach to the bottom bar in order to apply proper pre-tension to the fabric and to reduce the tension force on the structure. Eyebolts are attached to the springs to allow for maximum adjustability.

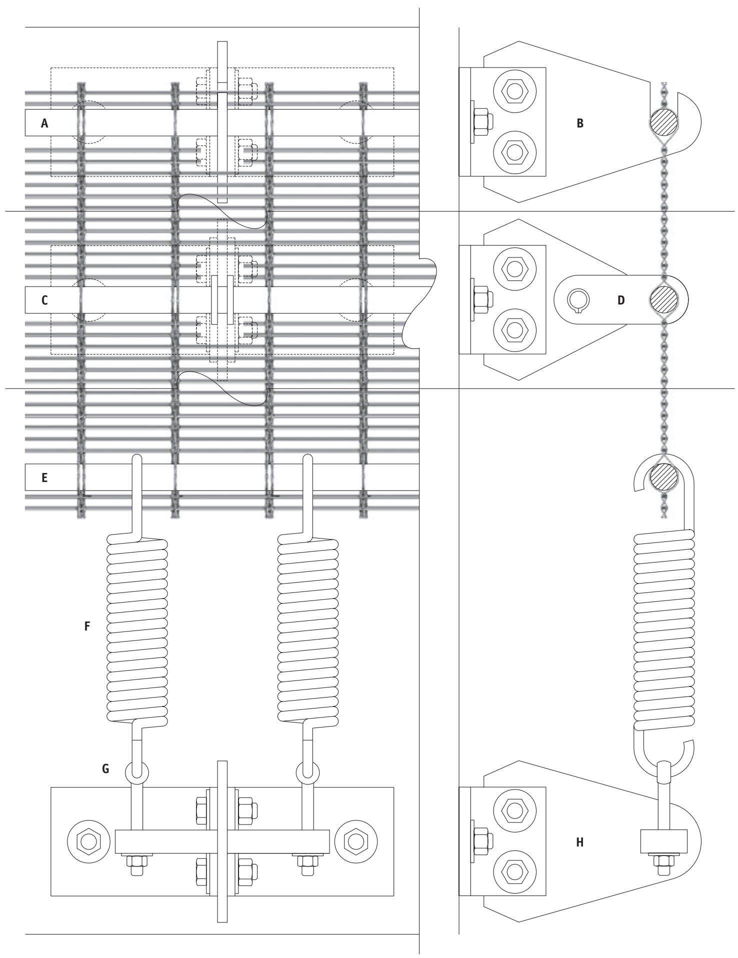
Shown with Tigris

Product compatibility
Escale 7x1
Futura 240
Futura 3110
Lago
Lamelle
Omega 1500
Omega 1510
Omega 1520
Omega 1530
Omega 1550
Sambesi
Tigris

Top
Woven-in round bar A
Hook attachment B

Intermediate
Woven-in round bar C
Pivot attachment D

Bottom
Woven-in round bar E
Tension spring F
Eyebolt G
Spring attachment H



Elevation

Side-view

These drawings are for reference only. They are not to scale. All hardware and attachments must be sized based upon your project requirements. Please consult GKD Engineering for further detailing assistance.

GKDMETALFABRICS

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Cambridge MD 21613

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F 410 221 0544
gkdmetalfabrics.com

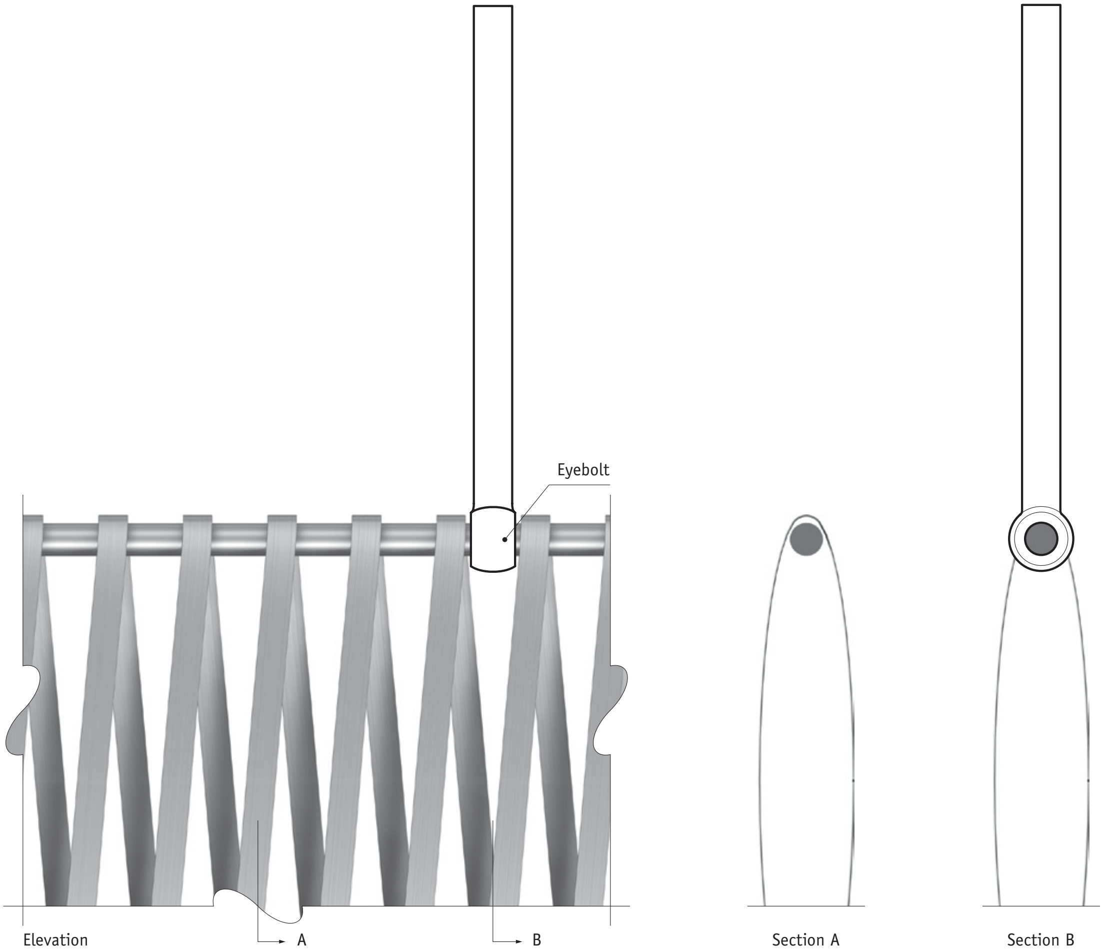
Eyebolt

Specific to the Escale products. An eyebolt is attached to the cross rod of the product and is tensioned by turnbuckle or nut. The eyebolt can be substituted with a hook.

Shown with Escale 7x1

These drawings are for reference only. They are not to scale. All hardware and attachments must be sized based upon your project requirements. Please consult GKD Engineering for further detailing assistance.

Product compatibility
Escale 7x1



PDF/0105

plant list (from Design Workshop Inc. 2008)

Trees

Acer glabrum	Rocky Mountain Maple
Alnus incana ssp. Tenuifolia	Thinleaf Alder
Betula occidentalis	Rocky Mountain Birch
Juniperus monosperma	One-seed Juniper
Juniperus scopolorum	Rocky Mountain Juniper
Populus angustifolia	Narrow Leaf Cottonwood
Picea pungens	Blue Spruce
Pinus contorta	Lodgepole Pine
Pinus ponderosa	Ponderosa Pine
Pseudotsuga menziesii	Douglas Fir
Populus tremuloides	Quaking Aspen

Shrubs

Arctostaphylos uva ursi	Kinnikinnik
Cercocarpus montanus	Mountain Mahogany
Cornus sericea	Red-osier Dogwood
Juniperus communis	Common Juniper
Mahonia repens	Oregon Grape
Paxistima myrsinites	Mountain Lover
Potentilla fruticosa	Shrubby Cinquefoil
Quercus gambellii	Shrub Oak, Gambel Oak
Rosa woodsii	Native Rose
Salix bebbiana	Bebb's Willow

Salix drummondiana	Drummond's Willow
Salix geyeriana	Geyer's Willow
Salix oreophilus	Common Snowberry
Symphoricarpos rotundifolius	Mountain Snowberry

Wildflowers and Forbes

Upland Perennials

Rudbeckia hirta	Black-eyed Susan
Gaillardia artistata	Blanket Flower
Rudbeckia spp.	Coneflower
Geranium richardsonii	Richardson's Geranium
Geranium viscossium	Sticky Geranium
Lupinus spp.	Lupine spp.
Penstemon spp.	Penstemon spp.

Riparian Perennials

Aquilegia caerulea	Colorado Columbine
Aquilegia elegantula	Western Red Columbine
Delphinium barbeyi	Tall Larkspur
Glycyrrhiza laphidota	Wild Licorice
Iris missouriensis	Rocky Mountain Iris
Mentha arvensis	Wild Mint
Pedicularis groenlandica	Elephanthead Lousewort
Polemonium reptans	Jacob's Ladder
Solidago canadensis	Canada Goldenrod

Upland Wildflower Mix

Aquilegia caerulea	Colorado Columbine
Aquilegia elegantula	Western Red Columbine
Balsamorhiza sagittata	Arrowleaf Balsamroot
Castilleja linariifolia	Narrowleaf Paintbrush
Epilobium angustifolium	Fireweed
Erigeron speciosus	Aspen Daisy
Gaillardia aristata	Blanket Flower
Geranium richardsonii	Richardson's Geranium
Geranium viscossium	Sticky Geranium
Heliomeris multiflora	Showy Goldeneye
Ipomopsis aggregata	Scarlet gilia
Linum lewisii	Native Blue Flax
Lupinus argenteus	ilvery Lupine
Penstemon strictus	Rocky Mountain Penstemon
Rudbeckia spp..	Coneflower

Riparian Wildflower Mix

Actaea rubra	Baneberry
Aquilegia caerulea	Colorado Columbine
Aquilegia elegantula	Western Red Columbine
Arnica latifolia	Clumped Arnica
Castilleja rhexifolia	Rosy Paintbrush
Castilleja miniata	Scarlet Paintbrush
Epilobium angustifolium	Fireweed
Hymenoxys hoopesii	Orange Sneezeweed
Iris missouriensis	Rocky Mountain Iris
Lathyrus lanszwertii	Aspen Peavine
Maianthemum racemosum var. aplexicaule	False Solomon's seal
Mertensia ciliata	Mountain Bluebells
Mimulus guttatus	Monkeyflower
Rudbeckia laciniata var. ampla	Tall Coneflower

Additional Forbes

Achillea millefolium	Western Yarrow
Aconitum columbianum	Monkshood
Aquilegia Formosa	Red Columbine
Campanula rotundifolia	Harebell
Chamerion angustifolium	Fireweed
Delphinium barbeyi	Subalpine Larkspur
Fragaria vesca	Wood's Strawberry
Gragaria virginiana	Wild Strawberry
Geum macrophyllum	Largeleaf Avens
Heracleum sphondylium	Cow Parsnip
Pedicularis groenlandica	Elephantella
Phacelia sericea	Silky Phacelia
Rudbekia occidentalis	Rayless, Coneflower
Senecio triangularis	Triangularleaf Senecio
Thalictrum fendleri	Fender Meadowrue

Grasses

Pitkin County Irrigated Seed Mix

Achnatherum hymenoides	Indian Ricegrass
Bromus marginatus	Mt. Brome
Elymus lanceolatus	Thickspike Wheatgrass
Elymus trachycaulus	Slender Wheatgrass
Festuca idahoensis	Idaho Fescue
Pascopyrum smithii	Western Wheatgrass
Pseudoregneria spicata	Secar Bluebunch
Stipa viridula	Green Needlegrass

Custom Site Dry Slope Seed Mix

Balsamorhiza sagittata	Arrowleaf Balsamroot
Bromus marginatus	Mountain Brome
Carex geyeri	Elk Sedge
Elymus trachycaulus	Slender Wheatgrass
Erigeron speciousus	Aspen Daisy (Showy Fleabane)
Festuca saximontana	Rocky Mountain Fescue
Ipomopsis aggregate	Scarlet Gilia
Poa secunda	Sandberg Bluegrass
Pascopyrum smithii	Western Wheatgrass
Penstemon strictus	Rocky Mountain Penstemon

Include 5% Sagebrush and Creeping Mahonia seed in grass mix.

Riparian Seed Mix

Calamagrostis canadensis	Bluejoint Reedgrass
Deschampsia caespitosa	Tufted Hairgrass
Elymus trachycaulus ssp. Trachycaulus	Slender Wheatgrass
Glyceria striata	Tall Mannagrass
Juncus arcticus (or J. balticus)	Arctic Rush (or Baltic Rush)
Koeleria macrantha	Prairie Junegrass
Poa palustris	Fowl Bluegrass
Sodar Elymus lanceolatus var. Sodar	Streambank Wheatgrass

Grass-like

Carex aquatilis	Water Sedge
Carex atrata	Dropping Blackened Sedge
Carex bebbii	Bebb's Sedge
Carex geyeri	Elk Sedge
Carex lanuginose	Woolly Sedge

Carex nebrascensis	Nebraska Sedge
Carex scopulorum	Mountain Sedge
Carex utriculata	Beaked Sedge
Eleocharis palustris	Creeping Spikerush
Juncus arcticus	Arctic Rush
Juncus confuses	Colorado Rush
Juncus ensifolius	Swordleaf Rush
Juncus longistylis	Longstyle Rush
Juncus mertensianus	Subalpine Rush
Juncus tenuis	Slender Rush
Schoenoplectus pungens	Bulrush
Scirpus microcarpus	Panicled Bulrush

Additional Grasses for Pitkin County Zone 4

Festuca thurberi	Thurber's fescue
Glyceria grandis	Mannagrass
Glyceria striata	Mannagrass
Leymus cinereus	Giant Wild Rye
Phleum commutatum	Alpine Timothy
Equisetum arvense	Horsetail
Equisetum hyemale	Tall Scouring-rush
Equisetum laevigatum	Smooth Scouring-rush
Equisetum variegatum	Slender Scouring-rush

Roof Garden Forbes

Achillea millefolium var. occidentalis	Western Yarrow
Artemisia cana	Silver Sagebrush
Artemisia frigida	Prairie Sagewort
Festuca ovina 'glauca'	Blue Fescue

Geranium richardsonii	Richardson's Geranium
Juniperus horizontalis	Creeping Juniper
Linum lewesii	Blue Flax
Mahonia repens	Creeping Mahonia
Penstemon strictus	Rocky Mountain Penstemon
Sedum lanceolata	Lanceleaf Stonecrop
Stipa viridula	Green Needlegrass

Suppliers

Aquatic and Wetland Company

999 Weld County Road 25, Fort Lupton, Colorado, 80621

303-442-4766

www.aquaticandwetland.com

Rocky Mountain Native Plants Co.

3780 Silt Mesa Road, Rifle, Colorado 81650

970-625-4769

native@aspeninfo.com

Western Native Seed

Coaldale, Colorado, 81222

719-942-3935

Westernnativeseed.com

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