The Soundscape Planning of Mountain Park in Holyoke, Massachusetts

THE SOUNDSCAPE PLANNING OF MOUNTAIN PARK IN HOLYOKE, MASSACHUSETTS

A Master's Project Presented

by

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INTRODUCTION

1.1 - Introduction to Soundscape Planning

The soundscape of a place is simply its acoustic environment, with the listener situated within the center of the sonic landscape (Porteous and Mastin, 1985). Soundscapes can be adjusted with proper planning, site analysis and design. Often overlooked by design and planning professionals, sounds are a part of the biological, social and spiritual context which needs to be considered if good outdoor environments are to be provided (Hedfors, 2003). With its close proximity to the Whiting Street Reservoir and Holyoke Range, Mountain Park provides a terrific opportunity for an outdoor amphitheater, a cultural resource deeply needed in Western Massachusetts. Significant landform and vegetation on site will greatly contribute to the acoustic opportunities and challenges of the site, while Interstate 91 provides an opportunity to mitigate the challenge of nearby noise pollution.

A community's atmosphere is determined by the acoustic space. This means that one's conception of what a landscape is today can no longer be restricted to what one sees and that community planning can no longer be content with noise control and abatement, but must pay attention to the character of the acoustic atmospheres of squares, pedestrian zones and of whole towns and cities (Bohme, 2000). Soundscape planning enables site planners to view sounds as a planning resource and landscape architects to view them as a design component. Landscape architecture affects all possible outdoor environments, including the corresponding soundscape (Hedfors, 2003).

Any strong soundscape design will take advantage of the favorable sounds throughout the site as well as prospect and refuge, if the opportunity on site provides itself. Sounds regarded as favorable include the twittering of birds and sounds of insects and frogs, wind movement in trees and grasses, and the sounds of streams (Brown and Muhar, 2004). An amphitheater nestled in a woodland setting is a prime spot for pure acoustics and breathtaking views. To achieve these acoustics, one must address the three approaches used by Pascal Amphoux in his work with sonic identity of European cities. The three approaches are: defensive, protecting the sonic environment from acoustic pollution; offensive, consolidating the acoustic milieu; and creative, composing the sonic landscape (Brown and Muhar, 2004).

The sounds of a location do not occur by chance; when people listen and notice the sounds that they create, they respond to their surroundings. The design, material and contents of the location invite activities and sounds which are associated with life and movement. The sounds say something about the landscape, the gardens and the spaces (Hedfors, 2003).

Because many amphitheaters are outdoors, some with little vegetation on site and in proximity to unwanted sounds, the design must take into account potential noise pollution and find potential ways to mitigate it. The soundscape planning of a site should look at a combination of sounds; the natural sounds of animals and weather paired with the environmental sounds of conversation, work and mechanical technology. The sounds create the acoustic ecology of a site and when these sounds are disrupted, this is called noise pollution.

To create a successful acoustic design for a performance space, noise pollution must be kept outside the site. There is, however, a difference between noise control and acoustic design, which is commonly referred to as soundscape planning. Noise control aims at protecting people who are indoors from noise generated outdoors – road traffic and aircraft noise for example. Soundscape planning is the planning and management of sound heard in open spaces (Brown and Muhar, 2004). Vegetation and landform buffers will help keep out the unwanted noise, while proper design of the amphitheater will help to enhance the acoustics of the performance within the space.

One of the finest examples of soundscape planning comes in the form of Red Rocks Amphitheater in Morrison, Colorado. With towering boulders flanking the amphitheater on both sides, it is hard to keep the focus exclusively on the stage and the extraordinary acoustics of the venue. The majority of human geography remains devoted to seeing the world, or speaking/writing about it, rather than to listening or hearing. Far too many people look at sites visually and do not take the time to listen to what exactly is happening in that specific space. The primary use of visual senses encourages us to neglect the role of all the senses in structuring and experiencing space and place (Smith, 1994). Many see sound as a problem to be managed, but landscape architects have realized that sound is truly a resource that needs to be utilized.

In the design of an outdoor amphitheater, there must be recognition of the presence of environmental noise, but not such a presence that it interferes with the

acoustics of the performance. There are many amphitheaters such as New England Dodge Music Center in Hartford, CT, that are located in urban environments with outstanding acoustics because of their structural makeup, but are lacking in both aesthetics and feelings of enjoyment. The fact that there are no sounds of natural environment because of the heavy roars of noise pollution deter many concert goers from attending events at these urban amphitheaters.

Advances in technology have aided soundscape planning tremendously; adjustable structures allow the acoustics of a room to be changed in minutes. Performances are recorded on nearly every occasion, and tests can be done, not only on the equipment used to amplify the sound, but on the media used to enhance it. In the music industry, it is increasingly apparent that the place of music – as a distinctive type of sound – is so important to the cultural turn in human geography that it merits a research agenda of its own (Smith, 1994).

With a state-of-the-art amphitheater, there are ample opportunities to turn Mountain Park into a large gathering space for local residents and once again see it become a destination in Western Massachusetts. Music is a very powerful resource and, if used correctly, can help define the nature of our relationships to each other and to the environment (Shepherd, 1991). With mountain vistas, roaming fields and wetland sanctuaries, if paired with live performances and recreational opportunities, there is great potential for all senses to be engaged on site. Sound, especially in the form of music, has a social and political significance which, if it could be heard, might influence, change or enrich the interpretation of particular scenes (Smith, 1994).

Mountain Park has such great potential to be a music amphitheater as well as an outdoor space for people to gather. The performances will initially attract the majority of the visitors, but once present, they can use all of the site's amenities, eventually creating a sense of community over time. Live music, being available only in a specific place to a limited audience, is particularly effective at serving a sense of community identity (Street, 1993). This is potentially good news for Holyoke, since the surrounding communities were dismayed when Mountain Park was initially closed; the city has remained optimistic about a new owner that could restore the property back to what it once was. The creation of an amphitheater could be a huge benefit to the community as

local music is a strong means of priming the pump of local economic development (Hudson, 1993).

1.2 - Goals and Objectives

The goal of this project is to bring to light the need for research of soundscape planning within the profession. Paired with the design application, research will identify techniques used in soundscape planning as well as amphitheater design. The research conducted in this research paper will be demonstrated in a master plan of Mountain Park.

Goals

- Research and identify innovative techniques in soundscape planning.
- To research and identify innovative techniques in sound amplification and modulation through the use of construction materials and landscape media as well as focusing on acoustical design of space.
- Provide Western Massachusetts with an experiential cultural resource.

Objectives

- Conduct a site analysis of Mountain Park and indentify areas that can be used in the design of a 7,000-person amphitheater as well as other activities.
- Demonstrate the application of soundscape planning through a conceptual design of Mountain Park.
- Identify program opportunities appropriate for the site.

1.3 - Justification of Project Study

Limited Research in a Visual Profession

As prevalent as sounds in the landscape are, soundscape research in the field of landscape architecture is uncommon. Issues concerning sound are mainly regarded as noise problems and are thus treated from technical perspectives, while certain sounds can be enhanced and noise problems mitigated through the design of landscape media (Hedfors, 2003). Critical site selection and planning are integral parts of proper soundscape design and show that planning also plays a large role in the process. The soundscape of a place should be included in the site analysis and studied early in the

project as the acoustic aspects of open space can, and should be, subject to design in the same way as are the visual dimensions (Brown and Muhar, 2004).

Supporting design documents are rarely formulated for acoustic environments (Hedfors, 2003). If sounds are to be considered on site and included in the project's results, then these documents need to be incorporated within the design stage. Sounds, both on and off site, are commonly left to the end of the design process. All locations can be expected to have a unique auditory identity (Hedfors, 2003), so to leave the soundscape design of a space to the end of the design process is a mistake. Enhancing onsite sounds can give a place a sense of identity, and by mitigating offsite sounds can help the users of the space further enjoy auditory refuge.

The professions of landscape architecture and regional planning have not developed any established knowledge about sound as a resource or element of design and planning, leaving a large gap in the research of soundscape management (Hedfors, 2003). For example, widths of pathways, depths of vegetative plantings, heights of trees and setbacks of buildings all have corresponding values that can aid in the layout of a design, but factual knowledge of sound impacts is missing. Each specific site has specific requirements and abilities, so research on acoustic decibel levels and adjacent land uses should be studied to help in site selection and zoning as well as the design process.

The ability to convey information regarding sounds within a space is rather difficult, as landscape architects produce creative visual renderings and models to establish alternative solutions to site design. These visual aids help determine the final layout of the acoustic environment, but the acoustic aspects are typically overlooked (Hedfors, 2003). Overlooking these aspects results in an acoustic design that never takes shape; the design process naturally focuses on the aesthetic features of the site and rarely incorporate soundscape analysis or design.

The limited research literature on soundscape planning within landscape architecture and regional planning has rendered the profession, predominantly, a visual profession. Sounds transmit information about the surroundings (Hedfors, 2003) and should not be considered a waste solely to be managed. Sounds need to be categorized and levels need to be tested during the site analysis process, so they are not left to the very end of the design stage, as is usually the case in the profession. The design of

landscape media should not only respond to the surrounding uses and connections, but their corresponding sounds as well.

Effects on Surrounding Land Use

Progressive planning can identify the framework for the soundscape of the future, since planners define the conditions and limitations of the project by which workers in the design stage must abide (Hedfors, 2003). The planning process is vital to the success of the soundscape planning of a project, since site development planning is not concerned with acoustic sources that are outside the boundaries of the project. Since the boundaries of the auditory space seldom coincide with those of the visual space (Hedfors, 2003), site selection and adjacent land uses must be carefully studied.

The texture of pavement, the location of different land use, the design of structures and the height of vegetation are all parts of landscape architecture and planning and have profound effects on the acoustic environment of any location (Hedfors, 2003). The natural acoustics of locations should be considered in the process of landscape planning. The planning stage involves determining the balance between preservation and development and inventory of sounds can drastically help in the design of the space. Acoustics should be considered in the choice and shaping of material as different materials have varying attenuations of sound.

Any sound-producing activities should be treated in association with questions concerning land use (Hedfors, 2003). The assignment of various activities on site is directly related to adjacent land uses and the sounds that they may potentially produce. Once site selection and place designations are complete, the shaping of the landscape through design can take place. Dealing with sounds both on and offsite early in the design and analysis process will create the proper future soundscape for that particular site.

Landscape architecture and regional planning professionals have learned to recognize the characteristics of particular types of land use, and building on this knowledge can help to determine various planning options for proper acoustic environments. Land uses have their own characteristics and associated sounds, and professionals need to be aware of these, as sounds can aid users to gain their bearings, orient within the site, identify activities, and experience various atmospheres in parks and gardens (Hedfors, 2003).

The planning stage is critical to the success of any soundscape design; proper site selection and location includes sufficient distance from surrounding noisy activities. An auditory refuge, which requires a spatial distribution area, refers to the development and protection of landscapes with various acoustic qualities (Hedfors, 2003). These areas can also be time-zoned, like a church on Sunday or the closing of business thoroughfare during peak shopping hours; within these times vehicular traffic may be limited or it may be prohibited to run certain machinery.

Restorative Benefits

Most music amphitheaters and outdoor performance spaces are not found in urban areas or surrounded by built development; most are found within state parks, protected lands or deep in the wilderness. Although the performance might be the main reason the patrons are there, it is often not the only reason. As people live their day-to-day lives, with the stresses of their jobs, families and money, the opportunity to relax in nature in multiple ways for sustained periods should be taken advantage of as the importance of nature in restoration cannot be overemphasized (Kaplan et. al, 1998).

It is not uncommon to see a large amphitheater that is either located within a protected area or directly next to one. Saratoga Performing Arts Center (SPAC) in Saratoga Springs, NY is a good example. Settled in Saratoga Spa State Park, concert-goers can spend their day wandering on the miles of hiking trails, playing in the natural springs or lounging by the river under a large grove of trees. There is no denying the considerable attraction of water in this landscape. Many waterfront areas are developed as greenways, providing opportunities for walking and biking as well as observing nature (Kaplan et. al, 1998).

The reason so many people seek natural settings is to relax and get away from the hubbub of their day-to-day lives. Time spent outdoors helps in regaining a sense of peacefulness; nature places and activities in natural settings are particularly effective (Kaplan et. al, 1998). Venues such as SPAC, Red Rocks Amphitheater in Colorado and The Gorge in Washington have been ranked in the top five outdoor amphitheaters in the country every year for the past several years; music-goers can spend their day in an absolutely gorgeous setting and then see a show at night.

In a research study on restorative environments done by Hartig, it was found that individuals returning from a wilderness trip are better at proofreading than members of a control group (Hartig et. al, 1991). This serves as a demonstration of how restorative experiences can lead to a clearer head, making it easier to tackle tasks that require great concentration. Restorative environments can allow one to focus on things that do not require any special effort, but are still inviting and fascinating. These quiet fascinations permit reflection; they make it possible to find out what is on one's mind. Fascination is the temporary relief of the everyday tasks of which one grows tired, and many natural environments have the capacity to evoke them (Kaplan et. al, 1998).

Although many of these amphitheaters are situated in large wooded areas or state parks, it is apparent that the space is well used during the majority of the day. People are extremely sensitive to indications that fellow humans are present or have been in a setting before as human elements in the natural setting are often comforting and highly preferred (Kaplan et. al, 1998). Another benefit of locating these performance spaces in protected lands or state parks is the opportunity to expand beyond a performance venue. For example, Red Rocks Amphitheater is situated in Red Rocks Park and is managed by the city and county of Denver. This affords the opportunity for the venue to be located within an extensive trail system that has clear signage and educational opportunities for all that it offers. When people feel oriented and confident that they can find their way around, their eagerness to explore an area is increased and their general anxieties are lessened (Kaplan et. al, 1998).

Concert Grassroots and Education

In the last five years, live music in a natural setting has become increasingly popular and the thriving industry shows no signs of slowing down. Not too long ago, attendance at live performances was dropping considerably, in large part due to the quality of performance spaces. With advances in technology and acoustic design, the quality of musicianship, sound amplification, and distribution of music have all jumped astronomically. With all these advances, live performances are taking new forms, with growing attendance and an abundance of opportunities to keep moving forward in design.

One of the most powerful aspects of marketing any product, especially live music, is grassroots promotion. Grassroots support is often the foundation of many successful

bands and/or venues. As music-goers travel the country listening to music and seeing new venues, they spread the word of all their experiences. That word gets spread from friend to friend via internet message boards, blogs and, social networks; very quickly, hundreds or even thousands of people can become aware of one person's experience. A superior venue or band can benefit from this type of marketing in a very short time, as word sometime spreads faster from Boston to San Francisco than it does from Boston to Providence (Baggott Interview, 2009).

As music fans travel around, they have the opportunity to see some of the finest venues with the best acoustics in the country. Unfortunately, they also see some of the worst venues and festival grounds. Venues such as New England Dodge Music Center in Hartford, CT sit in the middle of urban areas surrounded by parking lots and rail lines, with no opportunity to engage with nature or really have a full concert experience. Popular venues like Saratoga Performing Arts Center (SPAC) are highly visited because the fact that one can make the concert experience a full-day event. One can spend the day in a state park with friends and have some time to experience the park, not just the concert. SPAC is well-known for attracting throngs of people, many coming to sold-out shows without tickets just to experience its beautiful setting.

In terms of the largest grassroots music gathering in the United States, Bonnaroo Music and Arts Festival in Manchester, TN reigns supreme. While the 100,000 attendees enjoy one of the best music lineups of the summer, the grounds of the festival leave a lot to be desired. The 700-acre farm, with dirt roads and limited vegetation, house the four-day festival while people wander the grounds in search of their accommodations. Trees provide shade and shelter; they impart a sense of permanence and serve as landmarks to give the landscape form. It has been shown that wide open, undifferentiated areas are perceived to lack character (Kaplan et. al, 1998). In such instances, legibility is greatly reduced and complexity is lacking. An almost completely flat site leaves many undesirable views. Attendees are either burdened with a long wait in the front row, or with heads in the way, as seeing over the person in front of them is a difficult task. Large projection screens come to these people's aid, but the overall site and performance space could be so much more enhanced.

Without even realizing it, people quickly make decisions about places that translate to the feelings of fear or comfort. Being lost in a 700-acre field with tens of

thousands of strangers is enjoyable to some, but fearful to most. Feelings of security are closely related to what a person can see and whether it would be easy to move through the area. If the individual discerns obstacles, the desire to go farther is reduced (Kaplan et. al, 1998). Bonnaroo Music and Arts Festival is an example of a large flat site with vast open fields with little to no clear differentiation of spaces.

The grounds of Bonnaroo are very similar to those of many other music festivals, but Bonnaroo is an extreme example, as catering to 100,000 people is no simple task. Unfortunately, festivals in the 10,000 to 20,000 attendance range are also using the same setup as Bonnaroo. The stages are set in flat, open fields with no shade and limited recreational opportunities. The organizers of the festival need to go about installing landmarks within the grounds to help with wayfinding. There are some music festivals that hold their events on mountains, and this is a step in the right direction. Locating the stage at the bottom of a mountainside allows people to have an unobstructed view no matter where they are located. The mountainside setup also allows patrons to hike to the top of the slope and enjoy refuge from the performance, while still allowing clear acoustics and sightlines of the performance. The views captured from the top of the mountain can play an important role in wayfinding as well. In offering a bird's-eye view of an entire area, a vista can make it easier to develop a mental map of the setting (Kaplan et. al, 1998).

Creating a mental map of a site will help ease any anxiety that one might have of getting lost in a sea of people; being able to make sense of one's environment is critical to feeling competent, to feeling less fearful and overwhelmed (Kaplan et. al, 1998). From the mountainside, one can see parking, vending, stage areas, camping and medical services. When on ground level, one must refer to a map of the festival grounds, assuming that the production company provides one. Location of a festival or music gathering on a mountainside is already playing into the natural acoustics of a space. With any type of slope, the audience creates a 'back wall' to the performance space. The space they occupy absorbs the low-frequencies, naturally heightening the high-frequencies, giving the space a stronger presence of sound.

The location of a performance space on a mountainside also creates opportunities for recreation and relaxation. Many venues simply have the performance space and parking, offering nothing in terms of recreation. A venue should take advantage of the

opportunity to tie onto trail systems or the possibility to get people to lakes or rivers. If a venue can have a performance space, parking, camping, and recreation, they are doing much better than many other venues. These areas can be easily linked together, but easily divided up, so they are not read as one large space. Humans are discomforted by crossing big, open areas, preferring to stay near the edges. Dividing a very large area creates distinctive regions and therefore a safer, more manageable setting (Kaplan et. al, 1998).

At these large music gatherings, there is a significant opportunity for educating the public. With the increased awareness of sustainability and green technologies, live music performances have focused a lot of their time and resources on sustainability lectures and workshops, trying to reach out and make the people aware of the natural world. With this large demographic of individuals, there is a great opportunity to educate them about the earth and the resources that are increasingly dwindling away. Music festivals have become a great resource in educating the public about sustainability, energy conservation, and the music industry as a whole.

For passionate music-goers, one of the most unique aspects to seeing a live show is a completely stripped down acoustic performance. With advances in technology, amphitheaters use their large sound systems to amplify the sound to the furthest corners of the venue. The beauty of acoustic shows is the intimate feel, hearing the sound directly from the performers themselves; seeing the performance in its rawest form. For the majority, acoustic shows are amplified through speakers, but some bands play truly acoustic shows where they play with no amplification whatsoever.

Plan of Study

This project will incorporate research of soundscape planning, methods of sound amplification and the acoustical properties of materials and surfaces in the development of a conceptual design for a proposed 7,000-person amphitheater in Holyoke, MA. The amphitheater will have a speaker system for large shows, but with proper research and design, should be able to hold purely acoustic shows with no amplification of sound whatsoever. Mountain Park will also provide recreation and camping as it will be the site of the occasional music festival. Amphitheaters and performance spaces have gone the way of technology to amplify their sound, but a return to the natural setting of sound

amplification needs to be explored due to the high energy costs in making the show a reality.

LITERATURE REVIEW

2.1 - Acoustic Basics

The goal of any quality performance space is to create an optimal acoustic environment suitable for performance enhancement and audibility while protecting the hearing health of the individuals using that space (Acoustics, 2010). When dealing with acoustics, there are two types of rooms: a ‘dead room’ or a ‘live room.’ Live rooms are spaces with long reverberation times, while the sound in dead rooms dies out quickly. The two main factors in the creation of a live, acoustically strong room are reverberation time *(See Figure 1)* and reflection *(See Figure 2)* while the materials are tested for their noise reduction coefficient and sound transmission class.

Reverberation time is defined as the time required, in seconds, for the average sound in a room to decrease 60 decibels after a source stops generating sound (Acoustics, 2010). Throughout the design phase of a performance space, calculations must be done to demonstrate that the space will achieve the correct reverberation time. The challenge that lies within designing a performance space is the fact that different styles of music require different reverberation times. If the performance area is a multi-purpose space, designers have even more of a challenge as now they need to provide a space for speech, string music, choral music and rock concerts. Optimum reverberation times for speech are usually at or below the one second mark while orchestral music prefers a higher reverberation time, approximately two seconds would be appropriate. In the design of any multi-purpose performance space, there needs to be an appropriate balance, perhaps 1.5 seconds (Acoustics, 2010).

Long reverberation times are the result of highly reflective surfaces such as completely smooth walls. To get the desired reverberation time of a room, these reflections must be controlled to prevent unwanted sounds. Reflective corners or peaked ceilings create a megaphone effect, potentially causing annoying reflections and loud spaces. Reflections can be attributed to the shape of the space; parallel surfaces cause the acoustical problem called ‘standing waves.’ ‘Standing waves’ create a ‘fluttering’ effect between the two surfaces. At the same point, domes and concave surfaces are frowned

upon as they cause reflections to be focused rather than dispersed, which can cause annoying sound reflections. Concert halls that are designed for large-scale orchestral type performances are long and narrow, with nearly parallel walls on all sides creating reflections back onto the audience, mixing with the direct sound coming from the stage; speech and rock concerts are best held in fan-shaped auditoriums (Acoustics, 2010).

A main factor in comprehension of acoustics is the 'noise reduction coefficient' (NRC). The NRC is a single number index for the rating of how absorptive a material is (Acoustics, 2010). Absorptive surfaces are needed in any performance space as they eliminate reflection problems and help to control reverberation times. NRCs vary drastically from material to material, so careful thought needs to be put into what material is chosen for the design of the space. The NRC of a surface is measured by the mid-frequency of the sound. The sound can be measured anywhere from 250 – 4000 Hertz, typical high and low levels of musical performances and speech. The NRC, however, does not give information on how absorptive a material is in the low and high frequencies.

The last factor in the creation of a live room is the 'sound transmission class' (STC), a rating system of a material's ability for reducing sound transmission. The higher the number, the more efficient it is at reducing sound transmission. Ultimately, when sound is produced, there are three possibilities: the sound is reflected, absorbed, or transmitted. The absorption and reflection of sound depends on the materials that are covering the surface, while the transmission of the sound depends on the sound reduction capabilities of the surface itself. For example, loud speech can be understood fairly well through an STC 30 wall, but should not be audible through an STC 60 wall. Coupled with absorptive materials to reduce reflection and acquire the correct reverberation time for a space, surfaces with lower STC values can achieve the same results as a high-rated surface. As consistent with NRC ratings, STC ratings are only calculated on mid-frequency sound transfer.

Since there is a wide range of sound transfers in performance venues, special consideration of materials needs to be given to spaces that are going to hold performances other than speech. The material of the wall needs to be thoroughly researched, as well as the spacing between it and the absorptive material. Other considerations with STC ratings include air gaps between doorways and around ventilation systems. These gaps can have

a serious effect on the quality of the wall. Sound can find its way through wood, plumbing or ventilation systems; allowing noise to penetrate into the adjoining space (Acoustics, 2010).

Figures 1-2: Acoustic Basics

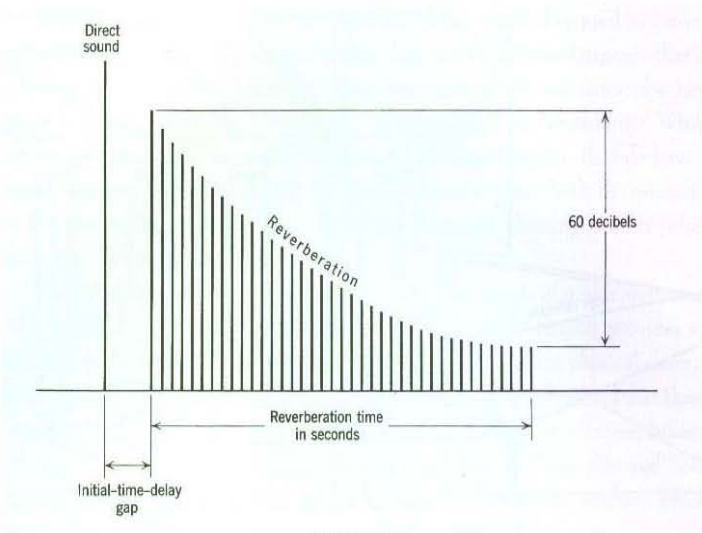


Figure 1

The volume of direct sound and the initial time delay gap before multiple reflections result in a rapid decay of sound.

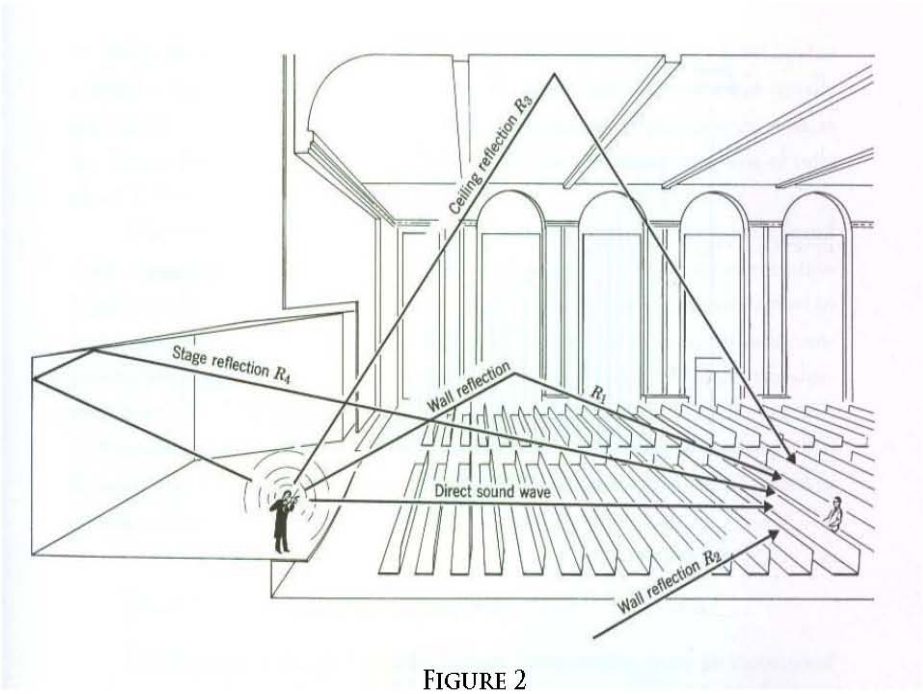


Figure 2

Sound paths traveling from player to listener, including direct sound; all these reflections occur under 80 milliseconds.

2.2 - Amphitheater Design

To provide the best acoustics capable of hosting a multitude of performances, the performance space needs to be enclosed. The sides of the performance space can be open, but should have an option of retractable walls so it can be completely enclosed for certain performances or weather conditions. There should be an open-air lawn for outdoor enjoyment and to provide the opportunity for more attendance in the case of a large event (Davis Interview, 2010). Since outdoor amphitheaters are usually located on sites that are used for activities other than just music performances, it should be enclosed with a privacy fence to guard against non-paid visitors.

It is to be a technical and artistic requirement that the outdoor theater should be made compact and intimate (Waugh, 1917). Music patrons appreciate and relish the opportunity to be close to the performer. When attending large 25,000 person amphitheaters such as New England Dodge Music Center in Hartford, CT, one can be hundreds of yards away from the stage and have to rely on PA systems and video screens to hear and see the performance. Both fans and artists can mutually inspire one another, if the crowd is excited so is the performer, and vice versa. Fans want to be up close, they want to hear the direct sound coming from the stage, not relayed through a PA system all the way into the back rows of a massive amphitheater.

When designing an outdoor performance space, orientation is key (Waugh, 1917). If the performance space is used at night, and most are, it can have almost any orientation. The worst arrangement is when the central axis of the theater runs due east and west, with the audience placed on the eastern end facing westward (Waugh, 1917). This arrangement leaves the afternoon sun falling directly in their eyes, while the opposite arrangement puts the sunlight directly in the eyes of the performers. For this reason, it is best to place an outdoor amphitheater with its axis running north to south. Of course, natural conditions such as topography are a factor for the orientation of a performance space, but if the site lends itself to a north/south orientation, it is best to do so. With the opportunity to place the amphitheater in this orientation, the audience should be placed at the southern end of the axis, if possible, leaving the setting sun out of the eyes of the paying audience, all the while creating a beautiful lighting effect upon the stage and its performers.

With the orientation determined, the next task is to enclose the space and keep the focus on the stage and its performers. The best method of securing privacy is found in the employment of trees, shrubs, and hedges, with large masses generally being the most useful (Waugh, 1917). The plantings that surround the performance space help create a sense of enclosure, discouraging unpaid intruders, as well as framing views of the performance. If the performance space is an open-air amphitheater with little to no backdrop, the most massive and monotonous plantings are to be located behind the stage, creating a neutral backdrop that attracts no attention. All eyes should be on the performance on stage; a lively composition of plantings with colored foliage and broken skyline is highly unsuitable (Waugh, 1917). As plant masses create the backdrop to the stage and enclosure to the sides of the space, some sort of wall or fence needs to run the periphery to ensure security. This wall could be brick or some sort of material that plays off the character of the plantings surrounding the performance space, but could turn into a more cost-effective material like a fence as it reaches the upper boundaries of the venue. The wall should be around the backstage area as well as around the sides of the venue, since this is where the performers will be spending most of their time.

Within any common outdoor amphitheater there are two distinct spaces. There is the performance space itself, with either chairs or lawn seating, and the gathering space where patrons can get away from the performance, use the restroom, meet friends, buy food and drinks, or just take in the views. In a normal amphitheater setting, the gathering space is usually at the top of the venue where the lawn plateaus and offers views of the performance from a different perspective. Red Rocks Amphitheater in Morrison, CO and Saratoga Performing Arts Center in Saratoga Springs, NY are very good examples of this. Offering views over the performance space, the upper plaza area is a gathering space that not only offers vending and bathroom services, but provides refuge from the concert experience. If there are splendid landscape views to be revealed they should be shown from vantage points outside the theater (Waugh, 1917).

The venue should be made for social interaction, offering gathering spaces both inside the performance space as well as out. Gathering areas, such as the upper plaza, should be directly in connection with the theater plan, offering friendly circulation for ease of movement throughout the venue. These gathering areas should be developed in connection with the performance space, while plantings, structures or similar features of

the theater should reinforce the connection between the two spaces (Waugh, 1917). The upper plaza should be the secondary space and accompany all other uses besides the performance itself. The majority of those in attendance are there for the performance so once the audience has taken their seats, there should be no competition of interests with what is happening on stage.

Now that the gathering space outside the performance space has been examined, the proper construction and layout within the performance space needs to be assessed. The stage setup is the most crucial to the success of a venue, since this is where the actual performance is held. Stage dimensions vary, but should be approximately 50 feet by 50 feet and have a high stage house, separated from the audience by the proscenium and often topped by a scenery loft. The stage house is the stage in combination with the space above it, while the proscenium is the opening in the wall that separates the stage from the audience. These arrangements detract from the acoustics of the space so it is required that side walls, ceiling and stage walls be irregular to provide good texture and diffusion of sound (White and White, 1980). A way to provide an irregular ceiling is with a moveable floor that is called a 'concert hall shaper,' which cuts off the upper portion of the stage house. With the 'concert hall shaper,' designers can provide optimum volumes within the performance space, while scenery and lights can be stored above it without reducing the liveness or warmth of the sound (Ando and Noson, 1997).

The 'concert hall shaper,' or better known as the orchestra shell, is comprised of individual panels that are not only to provide a ceiling to the stage house, but to distribute sound evenly between orchestra and balcony seating locations, as well as to provide reflections back to the musicians themselves *(See Figure 3)*. The high stage house fills with sound, providing more energy and warmth to the volume, while the reduced height of the openly spaced orchestra shell furnishes articulation, intimacy and on-stage hearing. The removal of the orchestra shell results in the reduction of loudness by 3 decibels and contributes to a substantial lack of clarity and sectional balancing within the performance *(See Figure 4)* (Ando and Noson, 1997).

Design of the stage area is vital to an acoustically strong performance space. The spacing and orientation of the walls, ceiling and stage house all affect the reverberation time of the room. With an adjustable ceiling like the orchestra shell, the time between two sounds, or initial time delay gap, is reduced. If the initial time delay gap exceeds

Figures 3-4: Orchestra Shell Graphs

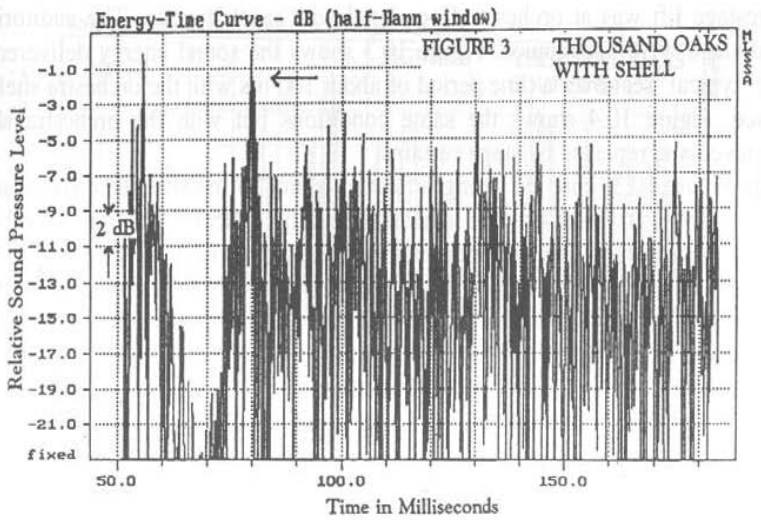


FIGURE 3

THIS GRAPH SHOWS ENERGY/TIME PATTERNS OF DIRECT SOUND AND REFLECTED SOUND IN A VENUE WITH AN ORCHESTRA SHELL. A STRONG REFLECTION COMES 25 MILLISECONDS AFTER THE DIRECT SOUND (ARROW) WHILE SOUND ENERGY IS LOUDER AND MORE EVENLY BROADCAST OVER THE DURATION.

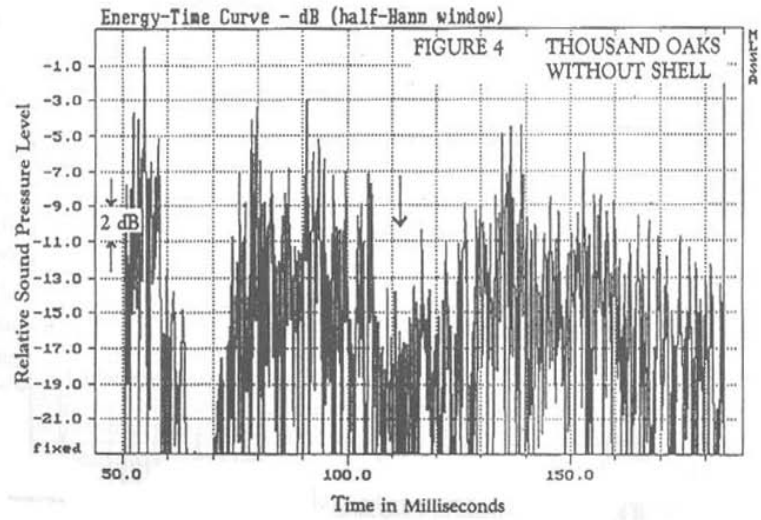


FIGURE 4

THIS GRAPH SHOWS ENERGY/TIME PATTERNS OF DIRECT SOUND AND REFLECTED SOUND IN A VENUE WITHOUT AN ORCHESTRA SHELL. THERE IS NO STRONG REFLECTION AFTER THE DIRECT SOUND, A LARGE HOLLOW OF SOUND REFLECTION EXISTS AT AROUND THE 55 MILLISECOND MARK AND LOUDNESS IS SUBSTANTIALLY REDUCED, AS SEEN BETWEEN THE 60 AND 70 MILLISECOND MARK. IT CAN ALSO BE SEEN THAT SOUND ENERGY FLUCTUATES SUBSTANTIALLY OVER THE DURATION.

50 milliseconds, the two sounds are heard separately, with the second sound being referred to as an ‘echo’ (White and White, 1980). If there is a large presence of highly reflective surfaces within the performance space, a series of echoes may be heard. With a properly constructed stage house, the initial time delay should be less than 35 milliseconds resulting in a single acoustic response to the listener that is of greater loudness and quality than the direct sound alone. A series of sounds originating within an interval of 35 milliseconds will be heard as a single sound, also known as a continuous reverberation (White and White, 1980).

Seating areas within most large amphitheaters usually comprise a reserved seating area that is closest to the stage, and a large general admission area that is located on the lawn at the back of the venue. The reserved seating portion directly in front of the stage is known as the orchestra pit and is usually filled with temporary chairs on a flat surface, as this is where the orchestra will be located during theater performances. Usually only 20 feet deep, this flat area slowly begins to slope up as permanent seating fills the rest of the covered portion of the venue. This flat space pushes the audience back a bit and helps with the acoustics of the space, as it is optimal for the performer to stand back from the audience, or slope, to optimize speech communication (Crisler, 1976). The flat seating area lends itself to a slight grade, usually between 2-5% (Kupferberg, 1976) and this is done so that everyone in the venue can see over the person seated in front of them. The grade of the reserved seating can exceed 5%, but is generally kept below 5% so handrails do not have to be implemented in the design. There should be unobstructed access to each seating aisle and this is easily achieved with the elimination of handrails. Many venues with indoor reserved seating provide a second level of seating that is located at the very back of the structure. One of the main goals of a performance space is to achieve uniformity of sound independent of the location of the listener. This is very hard to achieve, particularly when the listener is located underneath the balconies or at the rear of the venue (White and White, 1980).

The largest gathering space within an amphitheater is typically the lawn seating area. Completely uncovered, this general admission seating area has a direct connection to the reserved portion of the amphitheater. The gradient of this gathering space should be between 25-30% (Declercq and Dekeyser, 2007) to allow unobstructed sightlines to the stage. The steep gradient also provides a ‘back wall’ to the performance space,

helping to define the outer edges of the venue. This ‘back wall’ will help cut down on noise leaving the venue. Whenever creating an outdoor venue, designers need to be concerned about the noise impact on the surrounding land uses and be aware of any curfews that are set in place.

In the construction of theaters, the Greek construction process was much more efficient and cost-effective than the Roman. The Romans would create enormous structures to lift the crowd up high enough to have unobstructed sightlines. The Greeks would build the theaters on the slope of a hill, providing enough elevation for the back row of seats to have clear views and audibility. It is beneficial to have steeply-raked landform in the construction of amphitheaters because sound is to be projected in a line that grazes the audience’s heads. The high frequencies are then absorbed by the people’s hair and clothes, while the low frequencies are absorbed by the spaces in between the people (Crisler, 1976).

Circulation within the performance space should be simple and connected. Within the reserved seating portion of the amphitheater, aisles should be located on the periphery as well as two aisles between them, connecting the back of the covered seating area to the stage. These four aisles dissect the seating area into three pie shaped sections. Additionally, two aisles that are evenly spaced from the stage to the back of the seating area should connect the aisles that run along the periphery. These aisles break up the seating area into sections, allowing concert-goers better wayfinding and ushers an easier time of seating them. The aisles that run along the periphery should connect the indoor and outdoor seating, stretching from the stage all the way to the top of the venue at the upper plaza. These aisles should transition into wider pedestrian pathways once they reach the lawn area. A fence should be placed between the lawn and indoor seating to prevent any general admission ticket holders from sneaking down into the reserved seating. Another pedestrian pathway should run along the fence to connect the two sides of the lawn together. This flat pathway will provide access to pedestrians, but is accepted that it will fill up with standing viewers when the performance begins.

2.3 - Landscape Media

Proper design of landscape media: landform, plants, water and structure will help to enhance the natural acoustics of any space while providing definition for the design of

the site. The main focus of the section below will be how the landscape media helps in the reduction of noise both onsite and to the surrounding land uses.

Landform

The manipulation of landform is essential in creating an acoustically strong soundscape. An acoustically strong soundscape is that of which off-site noise pollution is mitigated, while on-site acoustics are enhanced the best possible volume. Landform is the basis for everything the design sits on and helps to create space for people to gather. Landform is essential in the creation of an amphitheater, as the proper grading creates unobstructed sightlines and multiple spaces within the venue.

As discussed earlier, most large amphitheaters consist of two parts, a reserved seating area that is closest to the stage, and a large general admission seating area that is located at the back of the venue. The proper gradients of each section are needed to provide proper acoustics and sightlines for viewers. The reserved seating, usually under a covered structure, is at a very minimal grade, while the outdoor seating on the lawn is much steeper. The steep gradient provides a 'back wall' to the performance space, helping to define the outer edges of the venue. This 'back wall' to the venue will help cut down on noise leaving the venue. Whenever creating an outdoor venue, designers need to be concerned about the noise impact on the surrounding community and be aware of any curfews or other restrictions.

The proper design of landform is the best way to keep out unwanted sounds. Landform buffers are a great method to protect a site from unsightly neighbors and loud surrounding land uses. They are common along interstate highways, as they are the best way to alleviate some of the noise that will make its way into the site. A 9-foot tall landform berm can attenuate sound by 15 decibels, making it a highly effective form of noise reduction (U.S. Department of Transportation, 2010). Landform berms deflect sound upwards; unlike a wall which will reflect sound directly back to the source. This deflection of sound upwards will direct the sound waves up and out of the space, while reflection off a wall will only enhance the loud sounds from the source. Since landform berms deflect sound upwards, sound attenuation is at its greatest directly next to the berm at its lowest point. Berms buffering unwanted sounds should be 6-10 feet in height, planted with mixed vegetation and located higher than the location that you are trying to

protect. Since sound waves go in the upward direction, the protected open space should be located much lower than the lowest point of the berm. If this is not possible, landform berms should be located at the closest point to the point source, attenuating sound as early as possible before the sound reaches the portion of the site that is trying to be protected (U.S. Department of Transportation, 2010).

Landform buffers are also a great way to control the amount of sound leaving a site. Large changes in elevation are the best way to attenuate sound, substantially diminishing the amount of noise leaving the site and ultimately affecting surrounding land uses. As stated above, noise travels upwards, so if sound can be directed into large elevation changes like tall berms or a mountainside, that should be done. This will severely cut down on the amount of sound that will be cast upon surrounding land uses and quiet portions of the site.

Plants

Vegetation has been proposed as a natural material to reduce noise energy outdoors (Aylor, 1972). A performance space should be confined to an area where only the sounds of the performance should be heard. Any noise pollution should be mitigated to the best of the designer's ability. Reflection, refraction, scattering, and absorption effects are due to any obstruction between a noise source and a receiver, which results in excess attenuation (Harris, 1979).

Vegetation within an actual performance space considerably cuts down on its acoustics, as tree-clad sites attenuate considerable low-frequency, little intermediate-frequency, and some high-frequency sound. The attenuation of low frequencies are in fact higher than the attenuation of high frequencies, but it was found that vegetation reduced sound equally for all frequencies between 200 and 2000 Hertz by Embleton in his 1963 study (Aylor, 1972). This shows that vegetation should not be located in any portion of a space where sound should be resonated. Vegetation and landform manipulation should be used to buffer sound, in turn enhancing the acoustics within the actual performance space.

Unless completely secluded in a remote location, performance venues usually have to deal with some form of noise pollution. Even then, noise pollution is almost unavoidable. To combat this, vegetative selection and design needs to be carefully

studied. Plant selection, ranging from coniferous to deciduous plant material, needs to be carefully thought out and executed. All the way down to branching characteristics and height of plantings, studies on proper plant selection need to be conducted as diverse forests attenuate nearly the same amount of sound. This means that old or young, planted or natural stands of trees are more or less equally effective in attenuating high-frequency noise (Aylor, 1972).

Sound sources come in two forms, a point source or a line source. An example of a point source would be a foghorn, while an example of a line source would be an interstate highway. Although in two different forms, the attenuation trends between line source and point source are similar (Fang and Ling, 2003). Noise pollution can be mitigated through suitable plantings like vegetative belts. Designers can reduce noise by six decibels through belts of tree and shrubs planted based on a one-meter visibility and five-meter width, or 10 meter visibility and 18 meter width (Fang and Ling, 2003).

Tree Belts and Buffers

Large belts of diverse vegetation need to be planted to help reduce any type of noise pollution. In a 2003 study, it was found that relative attenuation decreased with visibility and increased with width of tree belts. In the study, there were three separate groups used to determine the effects of noise reduction through plant selection and density. In group one; large shrubs were planted with a visibility of less than five meters, attributing to an attenuation that exceeded six decibels. Group two was comprised of trees and shrubs that had a visibility range between 6 and 19 meters; this group had an attenuation of 3 to 5.9 decibels. Lastly, group three was comprised of sparsely-distributed trees and shrubs whose visibility exceeded 20 meters, creating an attenuation of less than 2.9 decibels (Fang and Ling, 2003).

These findings show that there is a direct correlation between the density of tree-belt plantings and the attenuation of sound. At 2000 Hertz, there is a 40% increase in attenuation due to doubling plant density from 13 plants per m^2 to 27 plants per m^2 (Aylor, 1972) showing that density, height, length, and width of tree belts are the most effective factors in reducing noise rather than leaf size and branching characteristics (Cook and Haverbeke, 1971). To enable the tree belts to provide the best reduction effect, both trees and shrubs must be used, meaning shrubs should be planted under trees. More

specifically, low-branching trees and shrubs should be used so there is more surface area to absorb the sound (Fang and Ling, 2003). The primary goal of any good outdoor performance space should be the implementation of large vegetative buffers to prevent as much noise pollution on site as possible.

Leaf Density

Even though considerably less dense than coniferous trees, deciduous trees are still very good at reducing noise. Foliage reduces sound transmission substantially, especially at the higher frequencies where scattering is enhanced. With little foliage present, high-frequency sound is still reduced, mainly by stems (Aylor, 1972). Although it has been proven that leaf area and accompanying stems increase attenuation, especially at high frequencies, coniferous trees planted in the form of a tree belt are the most obvious factors in noise reduction (Cook and Haverbeke, 1971).

Sound attenuation increases with increasing leaf density; the reflection and transmission of noise energy through a leaf is dependent on the angle and surface area density of the leaf. The increasing width and leaf thickness is directly related to the reduction and scattering of noise, but is assumed that all the sound passed over, rather than through, a leaf. (Aylor, 1972).

Ground Surface

Scattering and ground attenuation are the principal factors in sound attenuation by vegetation (Aylor, 1972). Scattering is when sound is dispersed as a result of its reflection off various surfaces. The ground plane is rarely, if ever, the cause of scattering, so a study of the ground plane was conducted by Aylor. It was found that bare ground attenuates frequencies of 200 – 1000 Hertz, showing that ground attenuates considerable amounts of acoustic energy at lower frequencies. Studies also showed that soil permeability to the air were factors in sound attenuation. The tilling of soil reduced the frequency of peak attenuation from 700 to 350 Hertz and increased maximum attenuation at 52 meters from the source by nearly 80%. (Aylor, 1972).

This shows that the makeup of the ground plane and its porosity affect different frequencies. Porous surfaces have a phase lag because of the interaction of sound with the surface and the delay is larger the more porous the surface. This phase lag is an indicator that peak attenuation occurs at higher frequencies for hard or less porous surfaces (Aylor,

1972). When in sites with established forests or vegetation, decaying matter or fallen leaves and needles need to be taken into account. Because of their composition, the decaying matter would naturally attenuate lower frequencies, but overall have very little effect on attenuation. Tests on hardwood brush also indicated that recently fallen leaves had no noticeable effect on attenuation (Aylor, 1972).

Distance from Source

Since, in congested areas, people are more concerned with loudness and limited space, it seems logical to employ vegetative bands rather than large distances to achieve the same reduction in loudness. As a result of spatial constraints within a site, many designers do not have the option of providing large distances between the source of sound and what they are trying to protect. To accomplish the same reduction without vegetation requires that the distance between a point source and receiver be more than doubled (Aylor, 1972). With a line source of sound, similar to an interstate highway, a fourfold increase in distance is required to reduce the noise pollution.

The tests done by Aylor were done in close proximity to the sound source. It was found that the stems of hemlock, pine, and brush reduced a sound source of 4000 Hertz at a distance of 100 feet by 5 decibels. Since scattering and ground attenuation are considerably lower as distance from the sound source increases, measurements far from the point source are rarely taken. These long distances can underestimate the effect of a narrow band of vegetation or soil. Through multiple studies, it has been shown that sound attenuation is not linear with distance (Aylor, 1972).

As sound moves further from the source, more ground must be covered, severely cutting down on the distance it can travel at high volumes. From a point source in open space, sound is broadcast in a fan shape. As the sound travels further from the point source, it covers a wider range of space. At this pace, sound is exponentially decreasing over distance. Normal attenuation is due to spherical divergence and friction between atmospheric molecules when sound progresses. This has been termed the distance effect; noise attenuation increases with distance (Fang and Ling, 2003).

Water

The use of water is rarely explored in the design of performance spaces or large amphitheaters, but it was, however, used quite extensively in historic outdoor theaters.

The insertion of a pool or strip of water in between the stage and audience helped separate the two. The water provided not only effects for lighting, but also helped resonate sound from the stage (Waugh, 1917).

Water has been shown to broadcast sound instead of absorb it, as the ground plane. Acoustical tests were conducted on the shores of Galilee to prove this theory. Galilee is the home to a natural amphitheater that is fit into a cove with a steady slope leading up to a roadway. This is the exact location where large crowds would gather to hear the stories of Jesus. The tests were conducted on the shores of Galilee to determine if it was possible to find a spot with measurable acoustical properties sufficient to the gospel requirements (Crisler 1976).

A test was conducted where bursting balloons were located on a rock 30 feet off the shoreline in the cove's water with the receiver positioned 50 feet away. Another test had the bursting balloons located at the start of the slope with the receiver once again positioned 50 feet away. The results showed that the sound activity was much higher when the sound was coming from the center of the cove. The trace for the source at the center of the cove showed distinctly that quite a bit of reverberant energy arrived about one hundred milliseconds after the direct sound – a phenomenon not seen from the source at the start of the slope (Crisler 1976).

Since water is such an effective sound distributor, traffic, interstates or other loud uses should not be directed along waterways. Water causes the sounds of these land uses to be heard from much greater distances (Hedfors, 2003). Proper soundscape design looks at the enhancement of wanted sounds, and if located next to water, loud land uses will flood out these sounds. Water should be kept at a distance, with a proper buffer to any sound that is not meant to be enhanced.

Structures

Structures are one of the main components of any acoustically strong sounding performance space. Many of the specifications of structural design can be found in the amphitheater design section of the literature review, but the general use of structures in the landscape will be discussed here.

When a sound is produced in the open, sound waves spread outward in all directions. Performance spaces with high sound quality use structures to help direct

sound to the audience. Without using structures to define the space, sound can go in any direction, and at increasing distances from the source, sound energy is spread over an increasingly large area (White and White, 1980). Sound energy needs to be concentrated in the proper direction so it can be heard by all in attendance at the correct levels. The use of structures in a performance space helps direct sound and generates reflections, which in turn creates longer reverberation times. A venue needs the correct reverberation time for each performance type, ranging from speech to rock concerts.

The correct reverberation time can be accomplished by proper design of the structures. A fan-shaped performance space, with non-parallel walls is the best for large performances (Acoustics, 2010). Harsh reflections and poor sound diffusion are the results of peaked roofs and balconies, so these are discouraged in any design in search of superior acoustics. The non-parallel walls result in even distribution of sound throughout the performance space, as parallel walls create a 'fluttering' of sound that is detrimental to any performance.

Structures not only help concentrate sound in the correct manner, but also help to reduce noise pollution between the source and the listener. Sound waves are a form of energy and cannot simply disappear, but can change its direction and form (White and White, 1980). A covered structure over a portion of the audience not only helps protect patrons from noise pollution, but gives the ability to have completely indoor concerts when necessary. The mitigation of noise pollution is a major factor in strong acoustical design. Structures help to reflect, absorb, and transmit sound energy; this is beneficial in not only directing sound to the audience, but keeping out any unwanted noises.

2.4 - Materials

The proper choice of materials is crucial in the design of any strong sounding performance space. Materials directly affect reverberation times, the main factor that needs to be controlled to optimize the quality of sound. Reverberation is generally considered desirable for a musical performance, as it is probably the most important parameter in listening enjoyment. It increases the general loudness in an auditorium and causes the listener to feel enveloped in the music (White and White, 1980).

A strong-sounding performance venue should have a fullness of tone. Fullness of tone is the result of the proper reverberation time, usually between 1.5 and 2 seconds

(White and White, 1980). To achieve the desired reverberation time, designers must choose the proper amount of absorptive material that occupies the space. The correct amount of absorptive material is crucial to the success of the space, as too much will result in lack in fullness of tone, while too little will result in long reverberation times, which create echoes. With no absorbers at all, the walls of a performances space are smooth, causing fewer and more widely spaced reflections, resulting in a harsh texture (White and White, 1980).

When sound is produced, it has three possibilities: it can reflect off a material, be absorbed by a material, or transmit through the material. Sound insulators are a common material used to minimize sound transmission. Very little sound should be transmitted through a wall, as any sound leaving the performance space is detrimental to sound quality. Minimizing sound transmission through walls must be accomplished by maximizing the reflection or absorption, or both. Several materials and techniques have been implemented to achieve this; studies have indicated good insulation is determined by the mass of the wall. A thick concrete wall makes a fine insulator, particularly at high-frequencies, as the mass of the wall resists being pushed back and forth by the sound waves (White and White, 1980).

The main feature of the insulation of a performance space is the mass of the wall, but the stiffness of the wall also must be sufficient. Stiffness is helpful in suppressing the transmission of low-frequency sound *(See Figure 5)*. Although the stiffness of the wall helps sound insulation, the wall itself should not be the only material used. The chosen stiffness of the wall should be slightly reduced and sound absorption material should be draped over the wall to help reduce sound transmission (White and White, 1980).

Because of high construction expenses, many designers will opt to use a wall with less mass than desired. This is done by using a double wall with absorptive material in between the two *(See Figure 6)*. In either case, absorptive material should be used on the outer surface of the wall. Since the motion of air is greater slightly away from the reflecting surface, the absorptive material should be placed on panels and spaced somewhat away from the reflecting surface for best results *(See Figure 7)* (White and White, 1980).

Steel is the most common and recommended material to construct the venue out of because of its cost and durability. The steel structure diffuses sound well and has the

Figures 5-7: Sound Absorption

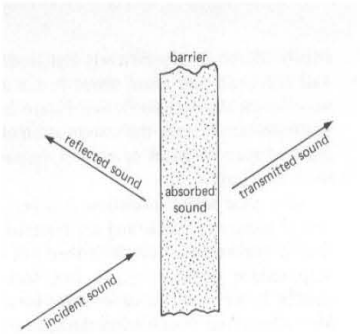


Figure 5

Sound can either be reflected, absorbed, or transmitted by a surface.

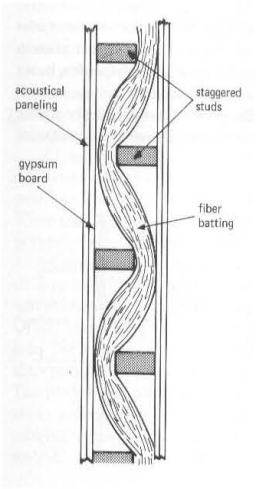


Figure 6

Example of double wall construction with absorptive material in between.

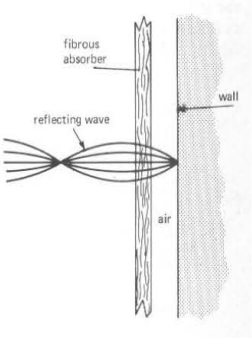


Figure 7

Absorptive materials placed away from reflecting walls will absorb sound by frictional damping.

ability to provide clear, rich, and resonant sound not only within the structure, but for a considerable distance beyond, like Tanglewood Music Shed (Kupferberg, 1976). The walls can be concrete or a double wooden wall with absorptive material between the walls, as well as on the outside. The shell and walls that make up the enclosure to the stage should be constructed of fiberglass to create resonance and clear definition of sound (Beranek, 2004).

Another method of sound absorption is to cover the surface with resonating cavities. The textured surfaced will enhance the rush of air in and out of the cavities. The 'friction' caused by the cavity walls will absorb the sound (White and White, 1980). Paired with placing absorptive material between the cavities and the wall, sound absorption will be enhanced even more. In addition to placing absorptive material between the double walls and over the exterior of the wall, careful attention must be paid to the filling in of the cracks left by ventilation systems and doorways.

Absorptive materials are not always used in performances spaces. If a room has good diffusion of sound and the proper reflections, almost no absorbers need to be used. Absorptive materials are used to control reverberation times as well as add to the warmth of the room. When a performance space lacks control of its acoustics, there is pressure on performers to play louder (White and White, 1980). National touring bands have set levels that they like to stay within, so the venue would need to have control of its acoustics, as the performers have control of theirs.

For a venue to have control of their acoustics, they must have the proper reverberation times for any type of performance. If the reverberation time is comparable with the time between notes, the notes seem to blend smoothly into each other. If the reverberation time is too long, there is a loss of clarity and definition as the individual notes played appear to blend together (White and White, 1980). This shows that matching proper reverberation times with performances is necessary to create the best possible sound. Reverberation times are determined by the volume of the performance space, but should match the type and tempo of the music whenever possible.

Since only a complete opening is a perfect absorber, it is necessary to consider the absorption coefficients of each surface individually in calculating reverberation times. For example, if a surface has a surface area of 20 m^2 and has an absorption coefficient of $x = 0.5$, then only half the sound striking it will be absorbed. In this example, the

absorption is equivalent to a perfect absorption surface of 10 m^2. The equation used to calculate reverberation time is known as Sabine's formula. The formula is T = 0.16 V/S where T is reverberation time, V is room volume and S is total absorption area. To figure proper absorptive materials and reverberation time, this formula should be used throughout the design process.

In most concert halls, the audience is the dominant absorber and could raise a whole other problem. To provide enough reverberation time, designers should use limited absorbers and use solid walls and ceiling materials that provide strong reflections. At the same point, performance spaces need to be prepared for the fact that not all performances will be full capacity. Each person in the audience has an absorption area of 0.4 m^2 (White and White, 1980), but when the venue is empty, only the seats are left to provide absorption. There is no way for a half empty venue to sound the same as when the venue is completely full, but for a performance space to have acoustics that do not change drastically with audience capacity, empty seats should have an absorption coefficient close to what it would be if a person was in attendance (White and White, 1980). Since absorption coefficients of an empty seat will never be the same as a person in the audience, reverberation times usually lengthen when the performance space is only partially full *(See Appendix for more on absorption coefficients).*

As a general rule of thumb, soft surfaces should be used for attenuation and absorption of sound, while hard surfaces should be used to resonate and enhance sound. Absorptive materials, landform buffers, vegetative buffers, and soft ground surfaces such as gravel, wet soil, or grass all attenuate sound, helping to either control reverberation time or drastically cut down on the amount of sound able to enter a site. Smooth walls, pavement, hard packed dirt surfaces, and water all reflect sound, causing a loss of control within the scope of reverberation time and mitigation of noise pollution.

2.5 - Case Studies

Tanglewood Music Shed

Tanglewood Music Shed, located in Lenox, MA, began in August 1934 when the New York Philharmonic performed at the first annual Interlocken Music Festival. It was such a success that the festival committee invited Serge Koussevitzky and the Boston Symphony Orchestra to participate the next year, bringing in over 15,000 people. The

following winter the Tappan family offered Tanglewood, their 210-acre estate, as a gift to Koussevitzky and the Boston Symphony Orchestra; they gladly accepted (Boston Symphony Orchestra, 2009).

The following summer saw the first festival at Tanglewood, which was performed under a large tent with a temporary stage. The second weekend of the festival had performances interrupted twice by thunder and rain storms. This was a turning point in the history of Tanglewood. As the audience sat under open umbrellas and made their way across flooded parking lots, plans were already being launched to raise money for a permanent music pavilion (Kupferberg, 1976).

Eliel Saarinen was chosen by Koussevitzky to design the structure. His design of a pie-shaped, open-sided structure included a vast audience area that fanned out in an arc from the stage *(See Figure 8)*. The initial design included studios, lecture halls, a library, as well as a Greek amphitheater, costing $167,000. With a budget of $100,000, Saarinen was asked to modify his plans, to which he drew up a new set of plans and told the Trustees that there was no way he could reduce the cost to less than $125,000. To come in closer to budget, the Trustees decided to hire on Joseph Franz of Stockbridge, MA, who was going to step in to help with some cost-saving renovations. Franz had the idea of erecting steel columns in the middle of the shed to simplify the overall design of the structure. This would result in obstructed sightlines, but would reduce the use of steel overall and cut the cost substantially. Saarinen unfortunately told Franz that if steel columns were introduced into the audience area, he no longer wanted to be associated with the project.

At the time of the construction of the Shed, it was erected $10,000 under budget and completed a month ahead of schedule; it is worth noting that the Shed was celebrated for the excellence of its sound from the very start. Many of the reasons for its superior sound are due to the cost-cutting measures that were done by Franz. He retained the plywood shell that provided resonance for the orchestra since its Hadley days, as well as leaving the inside of the Shed unfinished. The steel girders under the roof diffused the sound very well, preventing echoes or dead spots. With all these changes in design and budgeting, the Shed at Tanglewood was completed and now provides clear, rich and resonant sound not only within the structure, but for a considerable distance beyond (Kupferberg, 1976).

The only modification to the Shed occurred in 1958, when the temporary shell over the stage needed to be replaced. With high reverberation times and no surfaces to project the sound from the stage, the sound inside the Shed started to become ‘muddy’ (Beranek, 2004). The new shell helped to increase sound definition and enhance the tonal balance of the Shed. The stage, enclosed on its sides and rear by angled panels, could now hold any type of performance with the new shell *(See Figure 9)*. The side walls are serrated and sloped inward at the top, while fanning outward in plan view to direct sound to the audience seated in the pie-shaped sector of 110 degrees (Johnson et al, 1959). The new shell completely covered the stage and extended over ¼ of the seating area, as it is suspended half way between the floor and ceiling. This canopy is comprised of 26 non-planar plywood triangular panels joined at the corners, resulting in a pattern that is 50% open over the majority of the stage. The panels vary in width from seven to 26 feet and reflect about half of the early sound energy down onto the audience, arriving shortly after the direct sound; this gives the music the quality heard in classical rectangular halls (Beranek, 2004).

With a large open volume above the panels, the stage enclosure maintains a ratio of early sound energy to later reverberation sound energy that is optimal for the listeners. On stage, the enclosure is the primary reason for such optimal sectional balance within the ensemble playing. These optimal ratios were due to the location of the panels, which were determined by ray analysis. The open nature of the shell was designed to let sound pass into the high upper volume of the shed in order to retain energy in the long reverberation time which contributes to the desirable tones of the Shed (Johnson et al, 1959). The target reverberation time was two seconds at 500 Hertz with the Shed at full capacity.

With a capacity of 5,121 indoors, the lawn seating at Tanglewood can accommodate an extra 10,000 people. The bonus to the covered structure is the retractable walls that can enclose the space during an intimate performance or during an event that is held in the cold weather. The lawn provides the opportunity for viewers to experience the performance in a completely different way than those inside the venue. Patrons can sprawl out on a blanket, enjoy a picnic under the shade of a tree, throw a Frisbee or just dance around. The trees located on the lawn are natural plantings and have no real connection to the performance space itself. The pie-shaped design of the venue

Figures 8-9: Structural Design

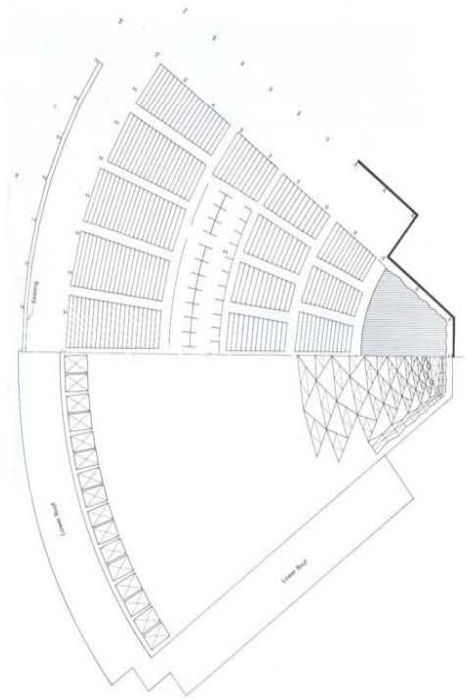


Figure 8

The fan-shaped design is best for concert performances due to the diffusion of sound as a result of non-parallel walls; parallel walls, peaked roofs and balconies create harsh reflections and concentrate sound in one particular area

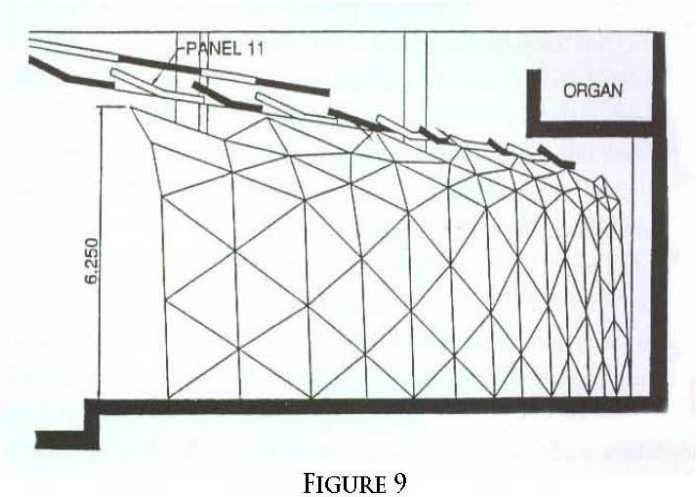


Figure 9

The orchestra shell creates the ability to be a multi-purpose performance space by having adjustable panels to help control reverberation time and diffusion and sound.

radiates from a stage that is 44 feet wide by 50 feet deep, and is constructed of 1.25-inch wood over a large airspace that is 33 inches in height. The side and rear walls around the stage are constructed of 0.75-inch painted fiberglass while the stage enclosure itself is 0.5-inch plywood with modulations in shape. The panels are suspended by steel cables from the ceiling, are heavily framed, and are connected tip to tip. The indoor seating is all wooden seating, with metal arms and no cushions. There are two main aisles that divide the venue into three separate pieces, making wayfinding much easier. The dimensions of the indoor venue are as follows: average height is 44 feet, average width is 200 feet and average length is 167 feet. Some technical details that are applicable to providing calculations to determine reverberation times are listed below.

Volume of hall: 1,500,000 cu. ft (42,490 cu. m)
Area of floor space with chairs: 24,000 sq. ft (2,230 sq. m)
Acoustical audience area: 30,800 sq. ft (2,861 sq. m)
Acoustical absorption area: 32,700 sq. ft (3,041 sq. m)

A study of the design and layout of Tanglewood Music Shed has helped to determine many of the size and sound issues that are directly applicable to Mountain Park. The owner of Mountain Park has expressed great interest in replicating something similar to Tanglewood Music Shed *(See Figure 10)*. With its ability to hold any type of performance, paired with acoustical conditions that rival the best in America, it is obvious why this venue is being looked at as a precedent. The adjustable panels allow the opportunity for a variety of performances, while the open-sided structure and unfinished interior helps to diffuse the sound and prevent echoes, dead spots, and concentration of sound. Circulation through the interior of the performance space is more common, since there is a reserved section and a general admission section within the amphitheater; therefore, connections between the two spaces should be studied as far as circulation is concerned.

Another feature very applicable to Mountain Park is the lawn seating that has an extensive, expansive capacity. A steeper grade than that provided at Tanglewood will be needed, but appropriate proportion and design, or lack thereof, can be derived from this case study. The retractable walls, which can be implemented for any performance, are a

Figure 10: Case Study - Tanglewood Music Shed

Source: Tanglewood, Google Earth

Tanglewood Facts

Capacity
5,121 inside; 10,000 outside

Structure
Covered amphitheater; open-sided

Stage Orientation
Northeast to Southwest

Design
The pie-shaped layout originates from a raised stage that is 50' x 40'. The indoor audience sits on wooden benches on a cement floor that is pitched 3% while lawn seating holds 10,000 people and is pitched slightly to maintain views of the stage while seated.

Acoustic Attributes
Open-sided, unfinished interior structure diffuses sound well; shell enclosing the stage helps provide balance and definition; adjustable panels provide an opportunity for a variety of performances.

feature of great interest to many venues as well as the pie-shaped layout that fans open from the stage. This layout is not best for multi-purpose performances, but is optimal for viewing. If Mountain Park focuses on aspects of Tanglewood like the serrated, inward facing panels that direct sound to the audience, any acoustical problems with the pie-shaped layout should be resolved.

Red Rocks Amphitheater

Red Rocks Amphitheater is a natural, geologically-formed, open-air amphitheater located in Morrison, CO, just 15 miles west of Denver. The amphitheater is located in the 868-acre Red Rocks Park set in the Rocky Mountain Foothills, where it provides some of the most picturesque views and expansive trail systems in the area. The main attraction to Red Rocks is the gigantic 300-foot sandstone monoliths flanking the stage on either side, creating not only a beautiful natural setting for a performance, but offering the closest thing to acoustic perfection (Red Rocks, 2009).

Red Rocks has been a world-renowned venue since its completion in 1947, even though it has been holding performances since the beginning of the 20th Century. John Walker, the first owner of the amphitheater, had the vision of performances nestled into this natural setting, holding a number of concerts on a temporary stage over a five year period. After years of trying to convince the city to buy the land, Walker finally sold the amphitheater to the city and county of Denver for $54,133 in 1927 (City and County of Denver, 2008). After purchasing the land, Denver architect Burnham Hoyt was contracted to design the amphitheater, keeping an emphasis on preserving the natural beauty of the area. Hoyt completed the design in 1936, and after 11 years of project construction, Red Rocks Amphitheater held its first event, the annual Easter Sunrise Service.

The area of Red Rocks, originally known as the Garden of Angels, was once listed as one of the Seven Natural Wonders of the World (City and County of Denver, 2008). The large monoliths, named Ship Rock (stage left) and Creation Rock (stage right) respectively, are is a look back into what life must have been like 250 million years ago. Stage Rock is a massive sandstone monolith tying Creation Rock and Ship Rock together, providing the back for the stage area.

There is no doubt that the main attraction to Red Rocks is the sandstone monoliths. These are the main attributes to the acoustic perfection of the venue as they encompass the stage on three sides. Stage Rock provides a back to the stage, both visually and acoustically, while Ship Rock and Creation Rock line the sides of the venue all the way to the very back of the amphitheater. Ship Rock runs at an angle and goes so far to the back of the amphitheater that it provides a 'back wall' of sorts. Creation Rock runs parallel to the seating of the venue, but still reaches the very back of the amphitheater (City and County of Denver, 2008). These monoliths lining the venue provide a surface for reflections of sound to bounce off. The intricate and complex faces of the stones create all sorts of possibilities for reflections of sound. Reflections can go to the back of front of the venue, but due to their unparallel faces, never directly back and forth between surfaces, thus avoiding a detrimental 'fluttering' of sound between the two stones (Acoustics, 2010). To avoid a 'fluttering' of sound, surfaces should never be parallel and have a slight batter. 'Batter' is the angle of the stone of which it is leaning. Stone walls have a better back into the earth, helping reinforce its strength, while the large stones of Red Rocks have a batter that angles back into the performance space, focusing the sound directly back into the audience within the performance space.

At its highest point, the upper plaza of the amphitheater sits at 6,200 feet above sea level and offers views over the top of Stage Rock and down across the landscape into the city of Denver (Red Rocks, 2009). This upper plaza creates a refuge from the music, but is still connected to the performance space itself. The venue places mostly all of their vending on the upper plaza as well as a second stage that provides the opportunity for a smaller band to get on the bill. This plaza is a nice place to meet friends within the venue, as the sea of people inside the performance space is daunting. With tree-lined pathways going up both sides of the venue, there is clear separation of circulation. The pathways tie the upper plaza down to the stage area and offer access to the performance space at any point along the path. The only trees inside the venue sit in planter boxes that double as meeting spots or even seating for the performance during a crowded event. There are only a couple dozen trees within the venue, all about 20 feet in height. These contribute to some attenuation of sound, but because of their small size and low number, have a very minimal affect on the sound of the space itself.

Because of its steep slope, every seat at Red Rocks is a good seat. The seating area consists of 70-tiered rows with a capacity of 9,450. The seats are wooden planks with no backs that are fastened to a cement foundation. The seats are terraced into the 30% slope and provide such an abundance of optimal seating that the audience helps to create a 'back wall' to the amphitheater (Red Rocks, 2009). This steep slope provides unobstructed sightlines throughout the entire venue, even those sitting behind front of house (FOH) in the center of the amphitheater can see over it. FOH is necessary in any performance space and is often a struggle for many venues. FOH runs the show; this is where the sound engineer and lighting director work. Red Rocks has a very low lying FOH and when paired with the steep slope of the seating area, offers almost no visual obstruction.

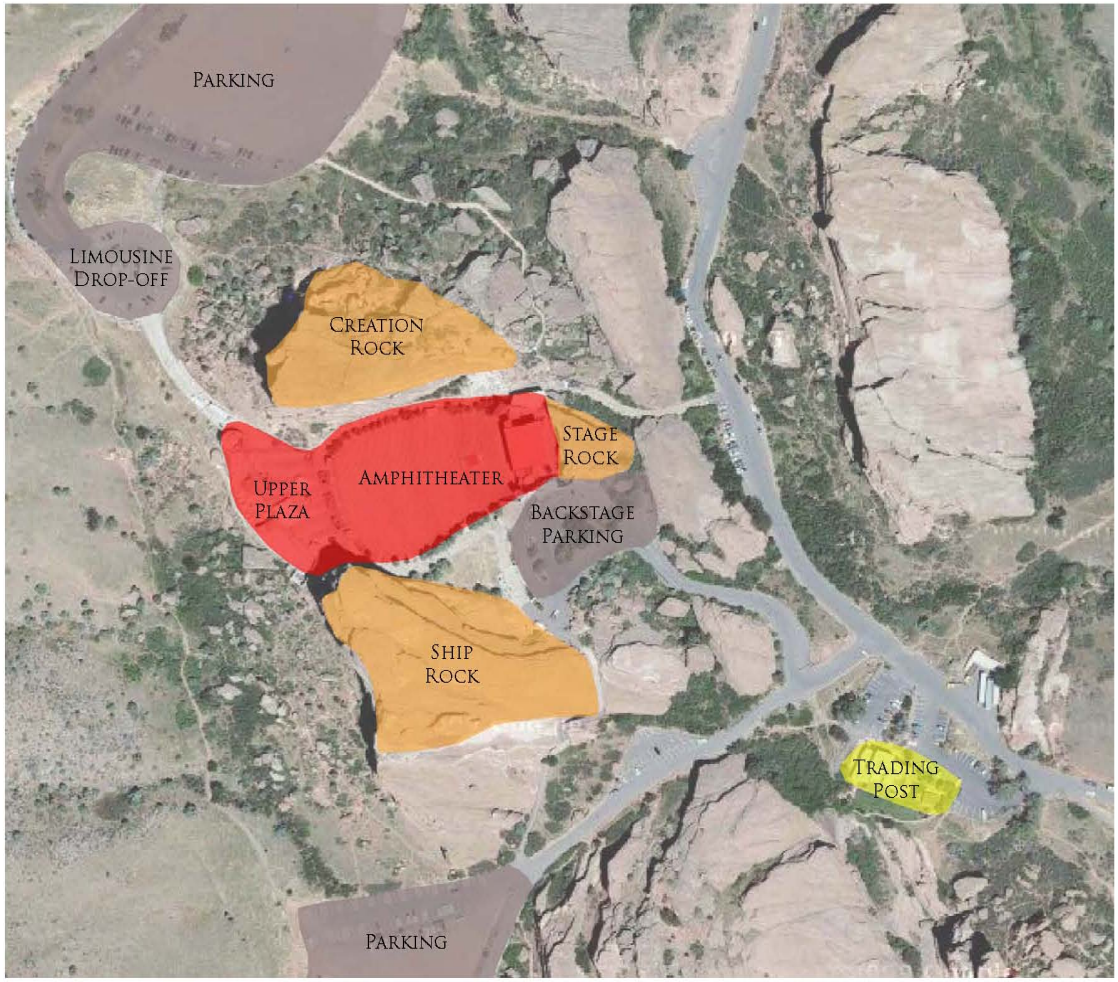
Parking at Red Rocks works very well, accommodating 3,500 vehicles in 14 lots. There are large parking lots on all sides of the venue, offering quick access to the performance space. A trail system goes around the amphitheater as there are hundreds of people seen at Red Rocks during the day, using the steep slope as a cross-training facility (City and County of Denver, 2008). The visitor center and memorabilia room are also heavily used, keeping Red Rocks in operation throughout the day.

The stage is a permanent concrete pad and is located only 10 feet from the first row of seats. The stage is 60 feet wide by 70 feet deep and has three access ramps, one from stage left and two from stage right. The roof over the stage is of beam-and-joist construction and has a 38,000 pound weight capacity, with a wind load of 100 mph. It also measures 60 feet wide by 70 feet deep and has a two-foot drop in height from downstage to upstage, meaning any snow, ice or rain will run to the back of the stage away from the audience (Red Rocks, 2009).

Red Rocks offers many good design ideas in the creation of an acoustically strong amphitheater *(See Figure 11)*. With a capacity similar to Mountain Park, Red Rocks was chosen for its strong acoustics and nearly rectilinear design. Holding Easter Sunrise Service, movies, and rock concerts, Red Rocks Amphitheater has been a multi-purpose performance space that should be intensively studied. Its clear separation of circulation from the performance space, as it ties all sides of the venue together is something that should be applied to Mountain Park. Trees and vegetation in general need to be kept to a minimum within the performance space, but lining the pathways with trees like Red

Rocks has merit. The upper plaza with its views of the city is another aspect that will be applied to Mountain Park. Sandstone monoliths cannot be replicated at Mountain Park, but the aspect of multi-faced surfaces will be used to prolong reverberation time, keeping the room as live sounding as possible. Lastly, the steep grade of the audience can be applied to the lawn seating of Mountain Park, as the covered structure for seating closest to the stage will be at a very minimal grade.

Figure 11: Case Study - Red Rocks Amphitheater



Source: Red Rocks Amphitheater Guide, Google Earth

Red Rocks Facts

Capacity
9,450

Structure
Open-air amphitheater; covered stage

Stage Orientation
East to West

Design
The narrow, almost rectilinear layout is nestled between three monolith stones. The upper plaza captures views of Denver and provides refuge from the concert as tree lined pathways separate the performance space from the circulation.

Acoustic Attributes
Monolith stones provide edges on three sides of the stage; multi faced surfaces contribute to longer reverberation times; 30% slope of amphitheater is best for projection and acts as a back wall.

Mayan Temples of Tikal

Tikal, located in the northern portion of Guatemala, was first inhabited in 900-BC when it was a small village. Several pyramids and temples were constructed between 500-BC and 100-AD, when it became an important ceremonial center. Tikal is the largest excavated site in the American continent, spanning 222 square miles. Following its rediscovery, it took over 13 years for archaeologists to uncover about 10 square miles of it, unearthing over 3,000 structures (Ecotourism and Adventure Specialists, 2009). At its peak of field research, Tikal was the home to more than 100 archaeologists, not to mention dozens of engineers and scientists. By comparison, Caracol, the largest Mayan ruin in Belize, had only two archaeologists working on it full time (Escobar Interview, 2010).

The climax of Mayan civilization in Tikal did not come until about 700-AD, when roughly 10,000 people lived in the city center. Tikal was similar to a wheel in that many spokes and concentric rings radiate out from the city center. These 'rings' of civilization were the home to another estimated 50,000 to 70,000 people, but population estimates reach upwards of 425,000 (Escobar Interview, 2010). Most of the ruins still visible today were built in this period. The ceremonial center of Tikal started to see a rapid decline in population around 850-AD, and is attested to a major drought at the time of major climate changes. On the grounds of Tikal, ten constructed reservoirs collect rainwater, as there were no springs, rivers or lakes nearby. Located in the covered jungle of northern Guatemala, Tikal was completely dependent upon the annual rainfall and this water catchment system for their daily living. As powerful as Tikal was, over the next 150 years almost all inhabitants had left, leaving the site completely abandoned by the end of the 10th Century.

Visited by over 450,000 people a year, Tikal's Mayan temples are renowned for their sound amplification and are of interest to many (Escobar Interview, 2010). These phenomena have kept the interest of scientists, archaeologists, engineers, and common folk for hundreds of years as their design, construction and acoustics continue to attract visitors from all over the world. As the common gathering space of its time, city centers would host several kinds of events. From meetings and sporting events to sacrifices and performances, no amplification was needed. Speech could be heard clearly throughout and every seat had clear sightlines.

As one stands at the top of a Mayan temple at Tikal, a whisper can be heard hundreds of feet away. Regular speaking voices are enhanced drastically; with scientists wondering how exactly these structures were engineered. With temples rising over 230 feet in the air, Tikal is home to some of the largest temples found at any Mayan site. The temples have no side structures to help enhance the acoustics; they are just towering temples that are constructed and arranged in such a manner that the site acoustics are exceptional. Most of the surrounding areas have long been overgrown by jungle, so the temples read as individual structures, making the acoustics even more impressive. People are heard yelling, clapping, and screaming throughout the grounds as the acoustics fascinate many visitors.

The reaction of first time visitors is usually to the size and construction of the structures, but is quickly followed by the recognition of the superior acoustics. With the growing amount of research that is present, the fascination with the almost mysterious acoustics of Mayan temples is growing. Researchers look at the construction of the temples as a whole, the materials they are made of, the batter of the stairs, the steep angle of the construction, the mathematics, the precisely-straight cutting of the stones, and the climate as factors contributing to the strong acoustics of Mayan temples.

The temples are constructed of limestone that was quarried on site (Escobar Interview, 2010). The result from the excavation of the limestone led to the formation of many of the reservoirs that the Mayan's used for their water catchment. The limestone material would be cut to a batter to enhance acoustics and aid in the overall appearance of the temple. The batter of most of the stones was two inches in for every 12 inches up. With the temples rising over 200 feet in the air, this batter gives the appearance of the temple leaning back, increasing the strength of construction. The limestone material, with a slight batter, was completely covered in stucco. Mostly all the stucco has slowly decayed over the years, but that has not diminished the acoustics of the space.

For centuries, scientists have spent great time and effort trying to figure out to what these acoustics were attributable. The geometric layout has been studied, but not until recently was it discovered that the materials of the construction were one of the main reasons for the strong acoustics. A study at Epidaurus in Greece, renowned for its extraordinary acoustics, found that the limestone used for the seating served as an acoustic filter. With no absorptive material, the limestone material would reflect the

higher frequencies while absorbing the lower ones (Declercq and Dekeyser, 2007). Low frequencies, like the deeper part of one's voice or surrounding mumbling from environmental sounds, would be absorbed, heightening the higher frequencies, which would naturally reflect off the surface. The batter of the material also contributes to the superior acoustics, as the angled steps create a longer reverberation time. While parallel walls produce a 'fluttering' sound between surfaces, battered steps help create reflections that prolong the duration of the sound.

The Mayan temples of Tikal offer quite a bit of insight on the proper construction of an acoustical sound amphitheater *(See Figure 12)*. With dense jungle surrounding the temples there is still very little sound absorption. The mathematics to build the temples at such a steep angle is impressive. The calculations had to be absolutely precise or the entire structure would collapse on itself. The steep angles of the temples help enhance sound within the area, not to mention the materials used in construction. The limestone material and the batter of the stairs both need to be taken into account when constructing the amphitheater at Mountain Park. Limestone is a rather expensive material, but hopefully a material can be used that has similar properties where low frequencies are absorbed and higher ones reflected. The batter of the stairs that make up the temple can be taken into account during the design of Mountain Park, as non parallel walls are vital to the success of any acoustically sound space.

Figure 12: Case Study - Mayan Temples of Tikal

Source: Francisco Escobar

Tikal Facts

Overview
Largest unearthed Mayan civilization; 900 BC to 950 AD

Construction
Temples grew in size as they were built on top of one another. Severe batter on all sides makes this possible and this is the reason the temples do not collapse to the ground. Batter increases strength as well as reflection of sound.

Materials
Large limestone stones were covered with stucco to help preserve the construction of the temples. Limestone's soft texture absorbs low frequencies and reflects high frequencies.

Acoustic Attributes
Limestone material absorbs low frequencies and reflects high frequencies, increasing acoustic quality; batter of construction helped reflection of sound without causing a fluttering of sound that parallel walls do.

NON-SITE SPECIFIC APPLICATION

3.1 – Methodology

To gain an understanding of soundscape planning and amphitheater design, a variety of methods were used. Included in the methodology is a study on how the process of research in soundscape planning should be conducted, a literature review with case studies, personal observations of amphitheaters and temples, a series of interviews, a site-specific analysis, and design recommendations for the project site. Below is a more detailed look into the methodology used on this project.

Soundscape Planning Research

A study on soundscape planning was conducted early in the project to justify the need for research in this field. The study showed that there truly is limited research about this topic in the profession of landscape architecture. Landscape architecture has tended to be a largely visual profession; therefore more research within this subject area could help to provide some insight into how to design with sound. The study also showed that exploration of how sound gives a sense of place and affects surrounding land uses needs to be pursued. A wide range of scholarship was reviewed on the restorative benefits of people being outside as well as the design techniques that can be used to heighten their experiences. Looking at the concert experience, a large demographic of people travel the world seeing music and these gatherings have turned into a huge educational opportunity. Through word of mouth, or grassroots promotion, well-designed spaces and their ample opportunities for education and recreation can be more widely and more quickly spread through the internet and across the country. Amplified by the passion of this growing demographic, any progressive design or development in the music business has a very strong chance of attracting a large group of supporters very quickly.

Literature Review

An extensive literature review was conducted to gain a stronger understanding of soundscape planning and amphitheater design. Included in the literature review were a variety of topics as well as three case studies. Exhaustive research on acoustics ranged from basic terminology to in-depth mathematical formulae used to prove the acoustical value of the space. Outdoor amphitheater design, the proper design and use of landscape

media and the materials of construction were also studied to determine applicable factors that can be used in proper soundscape design.

The three case studies used in the project were Tanglewood Music Shed, Red Rocks Amphitheater, and the Mayan Temples of Tikal. Tanglewood Music Shed in Lenox, MA is more comparable to what the amphitheater at Mountain Park will look like. The open-sided structure provides 5,000 seats under cover, while another 10,000 patrons can gather on the lawn. The design and strong acoustics of the venue have been studied extensively, because Tanglewood Music Shed is a multi-purpose performance space with adjustable panels that are located within the shell that covers the stage. Red Rocks Amphitheater in Morrison, CO is world-renowned for its extraordinary acoustics and how well it fits into its natural setting. This case study provided a look at an open-air amphitheater that provides unobstructed sightlines of the performance, paired with a refuge from the concert experience atop the upper plaza with views of downtown Denver. The last case study is the Mayan Temples of Tikal located in northern Guatemala. Tikal is one of the largest Mayan civilizations and has the largest temples in Central America. Towering over 230 feet in the air, the majority of these temples were arranged in plazas creating a central meeting space. The acoustics of the temples astonish visitors; whispers can be heard from hundreds of feet away. The materials and techniques of construction are the reason for the strong acoustics, and they have been studied extensively by many researchers in the field.

Personal Observations and Interviews

The past nine years of my life have been spent traveling the world, experiencing musical performances within venues ranging from 100,000 person music festivals and stadium shows down to the smallest of clubs and coffee shops. All the venues seen have their own advantages and disadvantages, from extraordinary acoustics to common design standards. All three case studies have been visited and extensive documentation was taken. Each case study visit looked at the design of the venue and, if applicable, the design of landscape media used to define the space and enhance the sound, as well as the site’s surrounding context.

Interviews and meetings have also been conducted to gain a better understanding of the sites being studied, acoustic design, and the music industry as a whole. The

interviews conducted were with Iron Horse Entertainment Group owner Eric Suher, Tikal tour guide Francisco Escobar, and a multitude of touring musicians and managers. An interview was also conducted with Brian Davis, the designer of New England Dodge Music Center in Hartford, CT, to help gain a better understanding of the design of the amphitheater. Although a much larger venue, New England Dodge Music Center is renowned for its acoustics; several bands do their pre-tour sound checks there because of its impeccable sound. This venue also has constraints similar to the Mountain Park site, as it sits directly adjacent to a highly traveled interstate.

Site Analysis

A thorough site analysis of Mountain Park was conducted to determine the proper location of the amphitheater, parking, concessions, and upper plaza. A history of Mountain Park and a study of its surrounding context helped to identify the existing conditions of the area in terms of opportunities and challenges. The detailed site analysis looked at the acoustics of the interstate and how it would affect the site. A study of the surrounding land uses and zoning helped to show what would be affected by the concert experience in addition to the interstate highway. Topography, wetlands, geology, vegetation, circulation, solar aspects, existing site features, acoustic decibel levels, and site amenities were also looked at to give a stronger understanding of the site.

Design Proposal and Recommendations

A design proposal and recommendations were created based upon the information gathered in this project study. The site analysis, conceptual drawings, sketches, and sections all aided in the creation of the site's master plan. The master plan was created as a demonstration of knowledge of proper soundscape planning. The research conducted provided specific information regarding amphitheater design, including but not limited to location and orientation of the amphitheater, angle of the slopes, placement of seating, materials used for construction, the role of vegetation, and the landform in the buffering of sound.

3.2 - Landscape Setting

The success of any outdoor amphitheater is in large part due to its location. Thorough and extensive planning must be completed to find the proper setting for an

outdoor amphitheater; while an in-depth site analysis must be completed to further understand what there is to work with on site. There are a variety of aspects that affect soundscape planning, but with proper planning, many of these can be eliminated.

Site Planning

Since the boundaries of the auditory space seldom coincide with those of the visual space, the planning process is vital to the success of the soundscape planning of a project. The natural acoustics of locations should be considered in the process of planning as the planning stage is when preservation and development are determined, and inventory of sounds can drastically help in the design of the space. Zoning and surrounding land uses play a huge role in the site planning and selection process, as these factors are directly related to the success of an outdoor performance space.

Any sound-producing activities should be treated in association with questions concerning land use. The assignment of various activities on site is directly related to adjacent land uses and the sounds that they potentially produce. Once site selection and place assignments are finalized, the shaping of the landscape through design can take place. Dealing with sounds both on and off-site early in the design and analysis process will create the proper future soundscape for that particular site.

The planning stage is absolutely critical to the success of any soundscape design; proper site selection and location includes sufficient distance from surrounding noisy activities. Proper planning will provide information regarding loud adjacent land uses like highways, industrial operations or flight patterns of airlines. These land uses should be kept at a considerable distance from a site that would like to produce a strong soundscape design. Since sound attenuates considerably over distance, these land uses can be located somewhat close in proximity, but are not recommended.

Proper planning will also show surrounding land uses that can be affected by the setting of the amphitheater. A substantial buffer between the space and residential land uses should be implemented. Residences are seldom located next to land uses with loud noise disturbances, so the setting of the amphitheater needs to be aware of whom it is affecting. Most cities and residential neighborhoods have strict curfews and some even have laws in place about decibel levels and how much noise a property can create.

Since water is such an effective sound distributor, traffic, interstates or other loud uses such as an outdoor amphitheater should not be directed along waterways. Water causes the sounds of these land uses to be heard from much greater distances. Proper soundscape design looks at the enhancement of wanted sounds, and if located next to water, loud land uses will flood out these sounds. Water should be kept at a distance, with a proper buffer to any sound that is not meant to be enhanced.

Site Selection

After the site-planning process is complete, a detailed site analysis must be completed to figure the validity of the site. If the site is properly situated, the manipulation of landform, plants, water and structure will be responsible for the strong acoustics of the design. Inventory of on and off-site sounds should be taken, as well as decibel levels of these sounds on site. Decibel levels of sounds, both on and off site, will help the designer in properly positioning the amphitheater and will show what areas need proper buffers installed.

If the site is adjacent to a loud land use, landform and vegetative buffers should be explored. If these buffers are not already in place, there should be plenty of space to implement them. Landform is the best form of landscape media in terms of sound attenuation, so installation of large berms between loud adjacent land uses is recommended. Large changes in grade between loud adjacent land uses and the site will help prevent noise pollution, naturally enhancing the sounds within the site.

A site with considerable grade change is best for housing an amphitheater. The site should have a space where the grade changes at least 30 feet so the amphitheater can obtain the 25-30% slope necessary for proper seating and acoustics. If possible, there should be a large, positive change in elevation from the top to the venue to the edge of the property, as this will help cut down on the amount of sound that is leaving the site. The site selected should also have an area that is relatively flat as venues have to accommodate a large amount of parking for performances. Large berms should define the edges of the parking lots as this is one of the loudest portions of a site besides the performance space.

The portion of the site where the amphitheater will be housed should have limited vegetation. Vegetation attenuates sound and should be used minimally, if at all, within

the confines of a performance space. There should be a variety of vegetation on site, though, creating a variety of spaces for users besides those within the amphitheater. Vegetation should be located at the very back of the venue, within the upper plaza, helping reduce the amount of sound leaving the site. A mix of deciduous and evergreen plant material is best, as combinations of trees, shrubs and groundcover provide the best screens to noise pollution. If possible, evergreen trees should be located on all sides of the amphitheater as they are the best in sound attenuation. These plantings will cut down on the amount of sound entering and exiting the amphitheater, which will only enhance the acoustics of the space.

A site with on-site structures and water is desirable. Existing structures most likely cannot or will not be used in the construction of the amphitheater, but can be used for some of the other uses such as concessions and vending, parking, or storage. Water bodies on site can have both good and bad aspects. If the presence of water is small, like a stream or wetland on the outer edges of the site, then the majority of the site will be buildable. If a large body of water is on or adjacent to the site, the amphitheater should be positioned away from it. Water is a strong distributor of sound, and amphitheaters holding performances aim to have as little impact on the surrounding land uses as possible. By directing sound away from water bodies, onsite sounds are not overpowered by the performance and sounds leaving the site are reduced.

A site with a trail system on or in close proximity to it is highly desirable. With many users of the performance space coming early to enjoy the site, spaces for recreation and resting should be provided. A large trail system, either onsite or in close proximity where it is possible to link to it, will provide users the opportunity to explore the site and the surrounding context. The ability to explore the site will help the users in orientation and creating a sense of place. Creating a sense of place for oneself or sense of community for large demographics will only aid in the success of the site.

3.3 – Program Specifications of Amphitheater Design

Below are technical specifications used in the construction of a partially enclosed, open-air amphitheater. These specifications have been compiled after extensive research had been conducted on the design, materials and construction of various amphitheaters and performance spaces.

Orientation

The best orientation of an amphitheater is with the central axis running north to south. This is the preferred setting, but may be limited by natural conditions such as topography. If the site allows, the audience should be situated at the southern end, keeping the sun out of their eyes. The worst possible orientation would be with the central axis running east to west with the audience seated on the eastern end. Depending on arrangement of the audience or performers, the setting sun will fall directly into the eyes of those looking west.

Covered Structure

Not all amphitheaters have covered structures, but a venue interested in being a multi-purpose performance space capable of holding all season events should consider this option. Dimensions of a covered structure with a 5,000-person capacity are as follows: 170 long, 200 wide, and 44 feet high. These dimensions include the stage which should 50 feet long by 50 feet wide and enclosed on three sides. Backstage amenities such as dressing rooms, lounges, bathrooms, and a loading dock are accounted for within these figures, but their actual dimensions are not provided.

The grade of the floor should be completely flat for the first 20 feet, since that is where the orchestra is located during theater performances. After this flat space, the grade of the floor within the covered structure should be 2-5%, allowing circulation between sections without the need for implementation of handrails. Railings should be located at the front and back of each section, separating the circulation from the seating, but no railings should be located along the sides. The pathways that connect the back of the reserved seating area to the stage run along the sides of each section and are heavily traveled. A fence should be located at the back of the covered structure to separate reserved seating from general admission lawn seating.

Walls within the covered structure, mostly around the stage area, should be non-parallel and irregular in pattern and texture. The walls that enclose the stage area should be slightly inward-facing at the top and fanning out in plan. The sides and rear of the covered structure should have the option to be closed off by retractable walls creating the ability for the venue to hold events in any weather. A ‘concert hall shaper,’ or orchestra shell, should cover the stage and ¼ of the audience. Located roughly half-way between

the audience and the ceiling, the orchestra shell is typically located 27-30 feet above the stage floor. The orchestra shell helps improve on-stage hearing, balance, and clarity for the performers, while providing evenly dispersed sound to the audience.

Walls around the stage should be covered with sufficient absorptive material. Amounts of absorptive material differ drastically depending on the materials chosen in the construction process. Paired with the ability to adjust the orchestra shell on stage, absorptive material will help cut down on reflections and transmission of sound within the performance space, and provide the correct reverberation time for the performance.

Lawn

Not all amphitheaters have a lawn, but with its capability for hosting general admission seating, dimensions and grades have been provided for performance spaces that would like to include it. Dimensions of lawn depth vary, but are not typically more than 150 to 200 feet from the back of the covered structure. The width of the lawn also varies because of its direct relation with the reserved covered seating area, but rarely goes beyond the boundaries of the exterior walls of the covered structure. Sound is designed to stay within the pie-shaped layout of most amphitheaters, so any person seated on the lawn outsides these boundaries will receive poorer sound quality than those located within the center of the performance space.

The grade of the lawn within the performance space should be 25-30%, allowing unobstructed sightlines over the crowd and down to the stage. The lawn will flatten out at the top of the venue, providing an upper plaza which will be discussed later. The lawn should also flatten out as it reaches the back of the covered structure, providing an area for pedestrian circulation from either side of the lawn. As indicated previously, a fence should be located at the back of the covered structure to separate reserved seating from general admission lawn seating. With such steep grades, circulation is directed to the outskirts of the space, cutting down on cross-circulation within the lawn seating.

Seating

Seating within an amphitheater can be constructed from several materials. Though limestone has proven to be one of the best materials acoustically for seating, it is far too expensive for a performance space. Due to cost of construction, performance venues

typically go for wooden, plastic, or upholstered seating. For a performance space to have acoustics that do not change drastically with audience capacity, empty seats should have an absorption coefficient close to what it would be if a person was in attendance. According to absorption coefficients of common building materials, upholstered seating had the closest absorption coefficient of an occupied seat versus an unoccupied seat. Wooden and plastic seats are better options for completely open-air amphitheaters, but cause harsh reflections and do not absorb low-frequencies as well.

As for seating within the amphitheater, permanent seats should only be located under the covered structure. The completely flat space directly in front of the stage, better known as the orchestra pit, shall have temporary chairs in place during concerts, but should be removed during performances when the orchestra is performing in this space. Due to its general admission nature, the lawn will have no physical seats, but landform can be graded in some areas to create the experience of a seat with a back. Other than those noted, no other seating should be located within the performance space or lawn area.

Upper Plaza

A large gathering space at the top of the venue should be provided for those looking for refuge from the concert experience while allowing a place for people to gather. The upper plaza should maintain views of the performance while providing a place for vending and bathrooms as well. It should provide alternative seating for those not wanting to sit within the performance space, as well as seating for those who are looking to eat or rest further from the concert experience. Lastly, it should provide views of not only the performance, but other onsite features and the surrounding context if possible.

Vending

Vending should be located in high visibility locations such as the main concourse and atop the upper plaza. These are areas where the crowd will collect outside of the concert experience. Vending should never be located within the performance space as it is an obtrusive feature in terms of acoustics and sightlines. Some vending is successful when located right next to the lower lawn, directly adjacent to the covered seating where access outside the performance space is quick.

Circulation

Circulation within the performance space should be simple and connected. Within the reserved seating portion of the amphitheater, aisles should be located on the periphery as well as two aisles in the center connecting the back of the covered seating area to the stage. These four aisles should dissect the seating area into three pie shaped sections. Additionally, two aisles that are evenly spaced from the stage to the back of the seating area should connect the aisles that run along the periphery. The aisles that run along the periphery should connect the indoor and outdoor seating, stretching from the stage all the way to the top of the venue at the upper plaza. These aisles should transition into wider pedestrian pathways once they reach the lawn area.

Due to the steepness of the slope of the lawn, an alternate path system must be used for handicap access to the upper plaza. Handicap access can be provided by ramps or a path system that goes along the very edge of the venue. A fence should be placed between the lawn and covered seating to prevent any general admission ticket holders from sneaking down into the reserved seating. Another pedestrian pathway should run along the fence to connect the two sides of the lawn together. This flat pathway will provide access to pedestrians, but is it is accepted that it will fill up with standing viewers once the performance begins.

Parking

A variety of parking options should be offered, both on and off site. Parking for tour buses and band personnel should be located directly adjacent to the stage. Limousine and VIP parking should be also be located close to the venue because they are paying a premium price. Moderately priced parking would follow the VIP parking in proximity to the stage with free parking provided after that. Free employee parking should be located at the furthest point from the stage, offering up the better spots to the paying public.

To alleviate the stress of the exiting process, where applicable, the roadway should be turned into a two-lane, one-way. This will allow tour buses and VIP paying patrons a quicker exit and ultimately easing the exiting process from the venue. Cones placed in the middle of the road can convert a road into a two-lane, one-way road. Due to limited on-site parking, Mountain Park should explore the option of satellite parking with a shuttle service provided to and from the venue.

MOUNTAIN PARK SITE

4.1 – Project Site History

Research and conceptual application with be conducted on a vacant parcel of land in Holyoke, MA known as Mountain Park. Complementary to a previous Master's project by MLA student Matt Medeiros, where a sustainable design for the venue was created, this acoustical design will benefit the landowner, Eric Suher, giving him a good idea of the next steps to be taken in the construction process of the venue. Mr. Suher is opening Mountain Park as his fifth venue under Iron Horse Entertainment Group, an entertainment company located close by in downtown Northampton. Mr. Suher has expressed interest in an acoustic design of the amphitheater, as he intends for the venue to be a multi-purpose performance space, holding not only concerts, but cultural and music festivals as well. During festivals, Mr. Suher would like to provide the opportunity for camping, and plans on bringing in the occasional amusement park ride; relating to the historical heart of what Mountain Park once was.

The site of Mountain Park is located in Holyoke, MA, the first planned city in the United States and current home of 40,000 residents. Because of its proximity to the Connecticut River, Holyoke, "The Paper City," flourished as an industrial powerhouse until the mid 20th century. With decline in city living conditions, Holyoke slowly lost its appeal and residents moved away. Now with one of the highest crime rates and lowest income levels ($30,441) in the state, Holyoke is in disrepair, with 26% of the population living below the poverty line (U.S. Census Bureau, 2008).

As grim as those facts sound, Holyoke has a lot of potential opportunities to work with. There are dozens of large, unused industrial-scale buildings that could be renovated into mixed use, business and housing. With its prime location along the Connecticut River and in close proximity to the intersection of two major interstates, Holyoke can attract a new work force. The Pioneer Valley is full of artisans and many of them have found a niche in Holyoke, so providing an affordable place for them to live, work and play is absolutely necessary.

Just north from downtown Holyoke, situated at the base of Little Mount Tom in the Holyoke Range, sits Mountain Park. It was purchased by William Loomis, owner of the Holyoke Street Railway Company, in the late 19th century. The park was converted

into a trolley park surrounded by gardens, concession stands, a roller coaster and other amusement park rides to take advantage of the terminus of the trolley line and encourage ridership (*See Images 1 and 2)*. The land on which the park sat was listed at 365 acres, but over the years, the reported actual acreage varied anywhere from 300 to 600 acres (Ducharme, 2008).

The park opened its doors in 1894 and as it expanded, evolved into one of the most beloved amusement parks in New England. Concurrent with the opening of the park, Holyoke was thriving. By the beginning of the 20th century, Holyoke's progress as a forward-thinking city attracted crowds of people who would in turn visit Mountain Park. William Loomis thought that citizens of Holyoke were looking for a recreation area, and he was correct. The grounds offered city folk a place of retreat on weekends, full of shade and wildlife. Mountain Park was a place of refuge for those who worked long hours in factories downtown. The pace of life one would experience at Mountain Park made it a popular attraction. One could enjoy the Whiting Reservoir, see music, or eat lunch under the giant shade groves found all over the site. The park was affordable for families and provided the opportunity to run into acquaintances (Ducharme, 2008).

With a bustling trolley system, residents of the area could easily make it to the park, the last stop on the line *(See Image 3)*. William Loomis eventually expanded the park to the top of Mount Tom, where he constructed the Summit House, a place for the public to gather and take in the sight of the Pioneer Valley. The same trolley system that provided access to Mountain Park climbed to the top of Mount Tom to provide all an opportunity to take in the views. In 1900, President William McKinley paid a visit with his wife and proclaimed the view, 'the most beautiful in the world.' Mountain Park could not have received a finer endorsement, and Mountain Park's popularity continued to grow (Ducharme, 2008).

In its very beginning stages, the park offered musical entertainment in the form of a small open-air theater where one could see a range of entertainment, from chamber music to theater shows. Less than five years later, however, the open-air stage was condemned and a new 2,500 person indoor performance space, known as the Casino, opened in 1900. This larger venue saw the music shift from big bands to rock and roll. By the 1960s, bands like the Beach Boys, Jerry Lee Lewis and Herman's Hermits would draw large crowds while the performance space would also hold sock hops and high

school proms. With direct access via the trolley line, Mountain Park was highly used at the time, but by the time the automobile became common around 1915, there was a dwindling need for it. Soon thereafter, cars would be lined up for miles waiting to get in; reaffirming that Mountain Park truly was the place in the valley where everyone met to hang out (Ducharme, 2008).

The gigantic rock that currently sits on the property was a popular feature at the park. It was used for climbing on and acted as a gathering space for those boarding the Northampton-bound trolley *(See Image 4)*. Near this rock was where the park expanded, opening a zoo, and providing an opportunity for city residents to see a small collection of wild animals. At this point, the trolley system was almost completely phased out, as buses appeared ready to replace the trolley system as the main source of public transportation. With this expansion, roadways and parking lots had to be created, taking with them many of the exotic trees and shade groves that were loved by so many for so long (Ducharme, 2008).

With the closing of the trolley system and eventual clearing of large parcels of land, recreation fields were a welcomed addition. As baseball became the dominant sport in the mid 20th century, a large field below Little Mount Tom was cleared for the use of sports or special events. On Tuesday nights, the field would be the launching pad for a fireworks display. With this offering, thousands of patrons could be found at Mountain Park not only during the daytime, but the evening hours as well. The closing of the trolley lines made way for recreation fields, but sadly rendered the Summit House atop Mount Tom almost completely useless. It had previously burned to the ground two times and now with little to no use of the trolley system, it was a decoration along the skyline, and nothing more (Ducharme, 2008).

The end of the trolley era, combined with the Great Depression, did not bode well for new owner, Louis Pellissier. In the 1950s, Mountain Park was sold by Pellissier to the Collins family, who already had a handful of established amusement parks. Many rides were added and renovated, bringing in a young, booming crowd. The park enjoyed success for over a decade before it slowly deteriorated. The Casino’s attempt to

Images 1-2: Mountain Park History

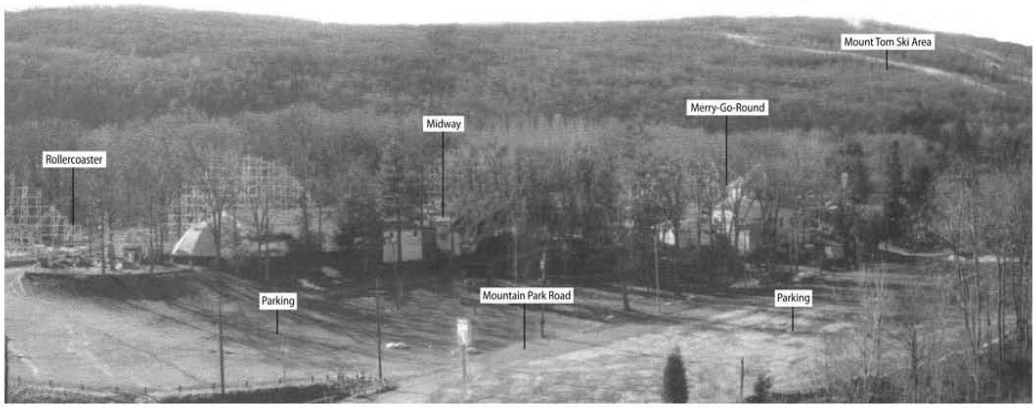


Image 1

This bird's eye view dating back to the 1960's was taken looking north from Interstate 91 showing the layout of the amusement park; mostly all development was to the west of Mountain Park Road.

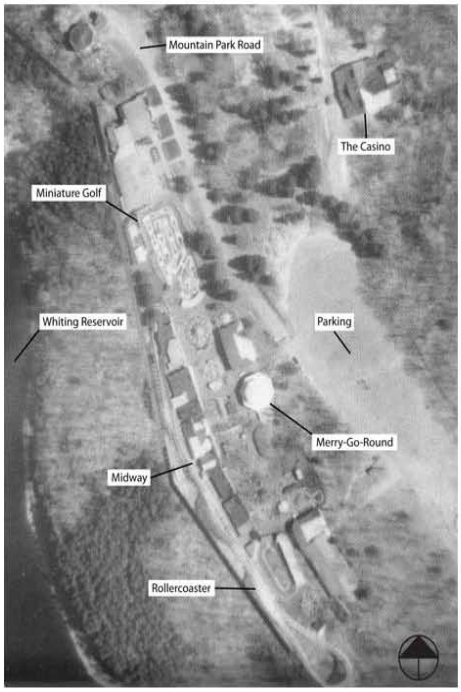


Image 2

Plan view of the amusement park taken circa 1960.

Images 3-4: Mountain Park History

Image 3

This image dating back to the 1960's shows Mountain Park as the lost stop on the trolley line; encouraging ridership and use of Mountain Park.

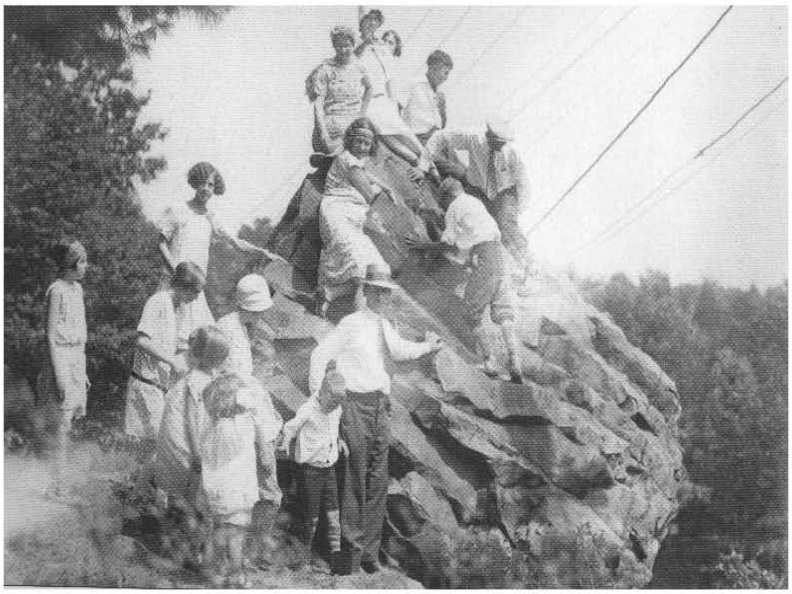


Image 4

This image dating back to the 1960's shows the existing rock on site as the popular gathering space that it was. Folks seen here are waiting for the Northampton bound trolley.

hold musicals, theatrical performances and rock concerts was failing. And after several of the buildings on site were ruined in an explosion, Collins decided that it was time for the Casino to be demolished.

By the 1980s, it was evident that Mountain Park was in decline. James Parsons, one of Collins' business partners, who were responsible for bringing in corporate events to the park, unfortunately passed away, taking lots of business with him. Paired with a state law that no longer allowed businesses to be open on Sunday, Mountain Park had little chance to adapt. Riverside Amusement Park, better known today as Six Flags New England in Agawam, was starting to see their number of visitor's rise, while Mountain Park saw a steady decline (Ducharme, 2008).

The park officially closed its doors in 1987. The surrounding community had hoped that the park would reopen, but a new owner would not be found until Mr. Suher purchased the property for $1.6 million in 2006. The parcel of land purchased by Mr. Suher was only 60 acres in size, as the remaining 250 acres has been turned into the Mount Tom State Reservation, which is owned by the Department of Conservation and Recreation to be kept as a nature preserve.

After three years in the making, Mountain Park held its first performance in the summer of 2009. Iron Horse Entertainment Group (IHEG) promoted a free music festival – a day of music that lasted into the early evening. The performance saw over 1,000 people in attendance as half a dozen bands performed throughout the day. The performance was held on a temporary stage, with all concessions being held in the only remaining structure on site, the picnic pavilion, which was home to the food concessions in Mountain Park's prime. After IHEG's genius marketing of a free music festival, national touring band The Decemberists came to the park one month later. This was the first paid event for Mountain Park, with over 1,700 people in attendance.

Many in Western Massachusetts are now aware of the plans for Mountain Park. After years of being quiet about his plans, Mr. Suher has unveiled plans for 'New England's Finest Amphitheater.' Still in the early stages of construction, Mountain Park will have a very similar setup to what patrons saw on those days in the summer of 2009. Gone are the trolley lines, the Casino and dozens of rides, but the memories, the laughter, and the future of Mountain Park will live on in another form.

4.2 – Site Analysis

The 60-acre site of Mountain Park sits in a very strong geographic location, only three miles from downtown Holyoke and eight miles from Northampton, respectively. The site is bordered to the east by Interstate 91, Route 5, the Connecticut River and the Pan Am rail line, with the only access coming from Route 5. Route 5 runs parallel to the Connecticut River as well as Interstate 91, linking Holyoke to Northampton and beyond. The Metacomet-Monadnock Trail and several bike trails are in close proximity, offering possible linkages to the greater context of trail systems *(See Figure 13)*. At the intersection of Route 5 and Mountain Park Road, a traffic light is in place, slowing down traffic and offering the opportunity to enter and exit the site safely. Large signage for the park is in preparation and will replace the outdated Mount Tom signage that is currently in place. Mountain Park Road provides direct access from Route 5 to the site with the overpass to Interstate 91 acting as the gateway to the park.

The Business Highway zoning designation of Mountain Park is surrounded by Residential Agricultural designation on all sides *(See Figure 14)*, most of which is protected open space in the Mount Tom State Reservation. Single and multi-family residential land uses are within a half mile of Mountain Park, contributing to the need for minimizing the sound impacts on surrounding land uses *(See Figure 15)*.

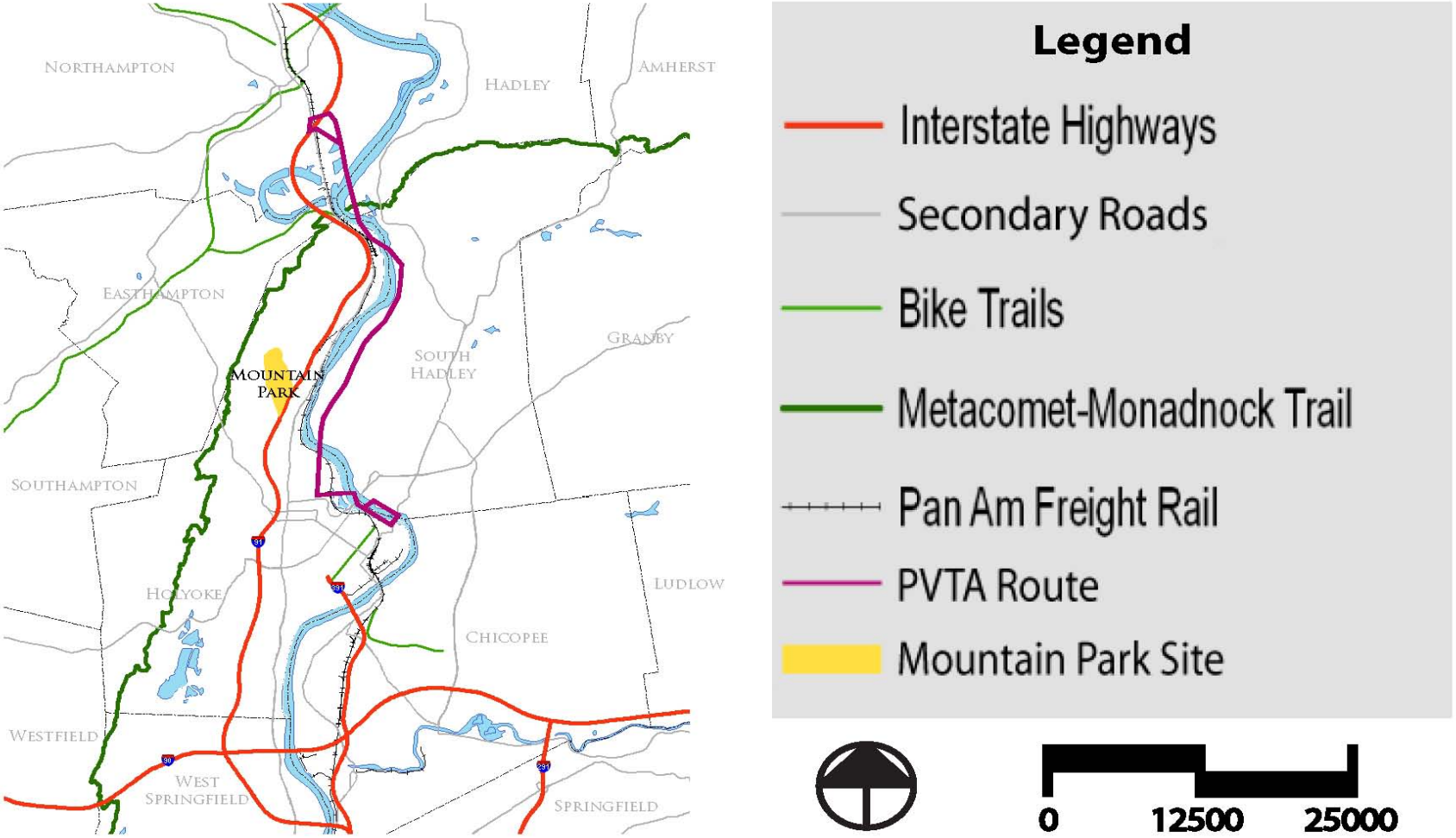
Topography

Situated at the base of Little Mount Tom, Mountain Park has a varying degree of topography on site. The site has an elevation change of 165 feet from Interstate 91 to the top of the site, where Mount Tom Ski Road cuts in front of Little Mount Tom. Steep slopes of 15 to 20% along the southeastern side of the interstate help to buffer sound, while slopes of 15 to 20% along the northwestern side of the interstate slowly turn into slopes of 5 to 10% before reaching an offsite wetland. The grade change between the highway and the top of the landform bordering both sides of the highway is roughly 20 feet, but turns into a five-foot grade change where the off-site wetland lies. This change in landform will drastically affect the noise pollution that enters the site, but the steep landform and large grade change surrounding the rest of the interstate is a sufficient buffer and cuts down on a significant amount of the noise pollution coming from the highway.

Bordering the northern portion of the site, the mountainside of Little Mount Tom has slopes ranging from 25 to 35%, while the Mount Tom Ski Area and surrounding mountain range has slopes of 15 to 20%. For the majority of the site, all land to the west of Mount Tom Ski Road is between 0 and 10% slopes with only a few exceptions. Steep slopes of 15 to 20% are located all along the Mount Tom Ski Road as the gradient changes from mountainside to rather gentle, rolling landform. Slopes of 15 to 20% exist in only a few spots within the boundaries of the site; one of these spots is located at the northern terminus of Mountain Park Road. The landform in this area is steep because of the fact that a large area of 0 to 5% slopes exists at the highest point onsite. This large, flat area is bordered by slopes of 15 to 20% that are necessary to get back to the grade of Mount Tom Ski Road. The steep slopes at the top portion of the site are conducive to taking in the views over the Connecticut River to South Hadley, the water tower and some of those most beautiful farmland and conservation areas in the Pioneer Valley.

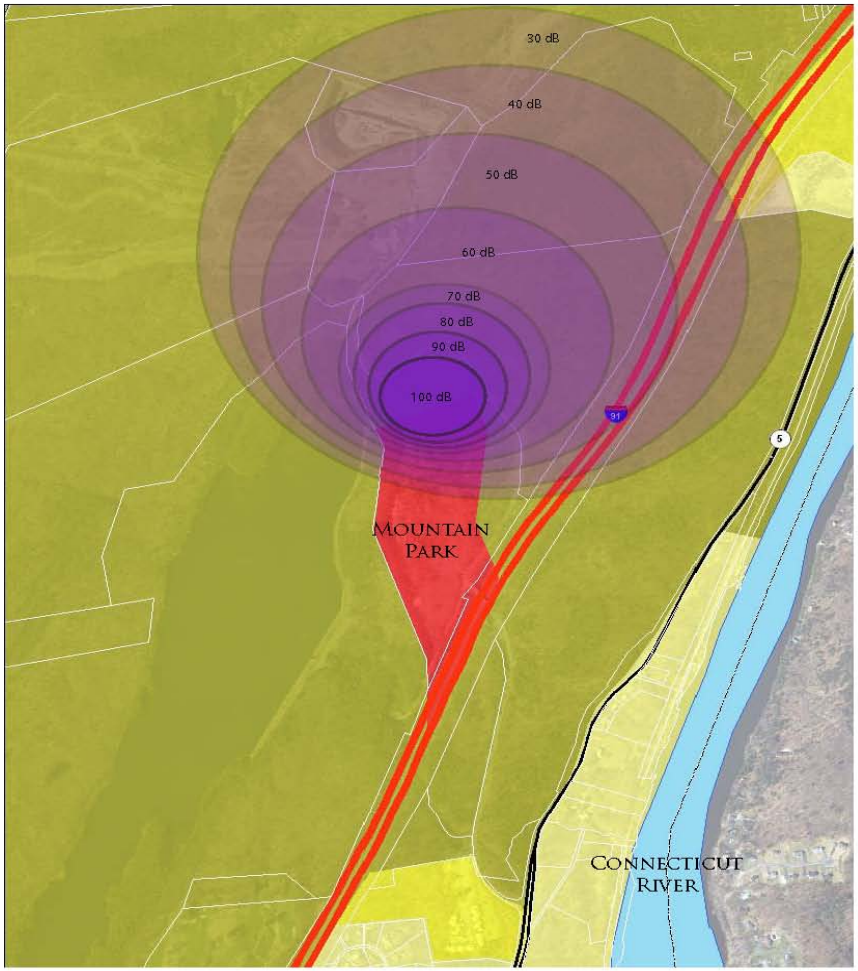
The landform to the west of Mountain Park Road slopes gently uphill to a large, flat portion of the site. A small area with a steep slope of 10 to 15% rises 15 feet above Mountain Park Road and creates a strong buffer between the roadway and the flat, large open space. This open space takes up a large portion of the site, and is bordered by steep landform to the west, roughly a 10% slope up before meeting grade with the forest and the heavy vegetation that borders the site. These 10% slopes run along the entire western portion of the site and help define where the 60 acre parcel ends. To the east of Mountain Park road, 5 to 10% slopes help the transition from roadway to open space. The highest point on site is surrounded by steep slopes of 15 to 20% while the 5 to 10% grades gently slope down to the lowest point on site where a wetland exists. The slopes in the center of the site that range from 0 to 10% provide a great space for recreational opportunities, picnic areas, and camping. Directly next to the entrance of the site is a large area that is completely flat and could provide for overflow parking when the opportunity of a large scale event presents itself, or has the potential to house temporary amusement park rides *(See Figure 16)*.

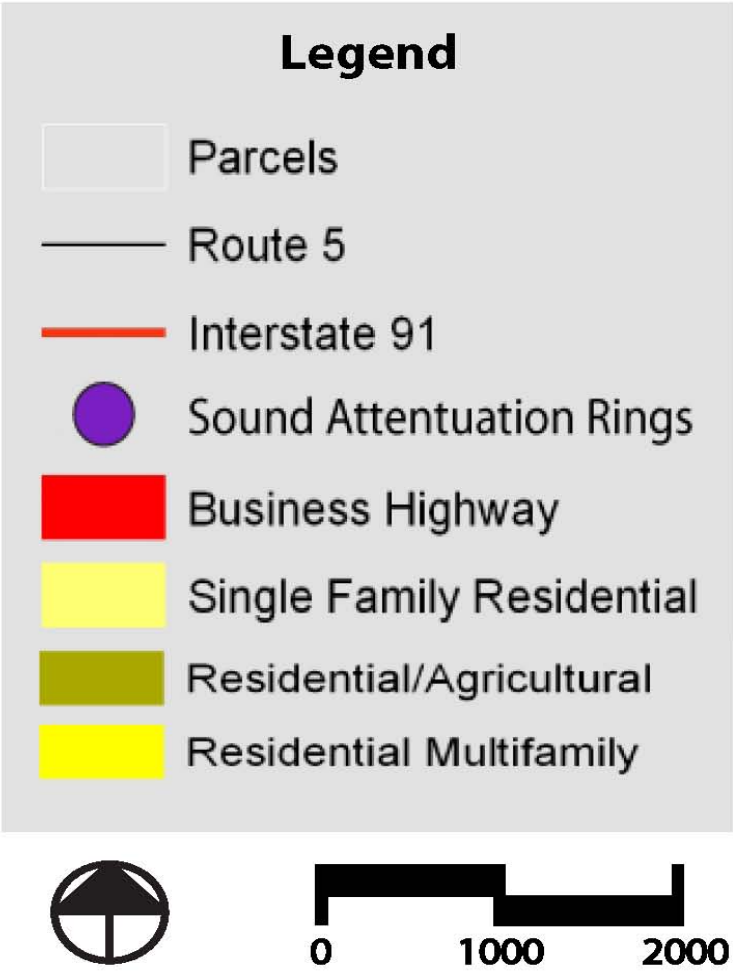
Figure 13: Regional Context of Mountain Park



Source: MassGIS 2000, PVTA, Matt Medeiros

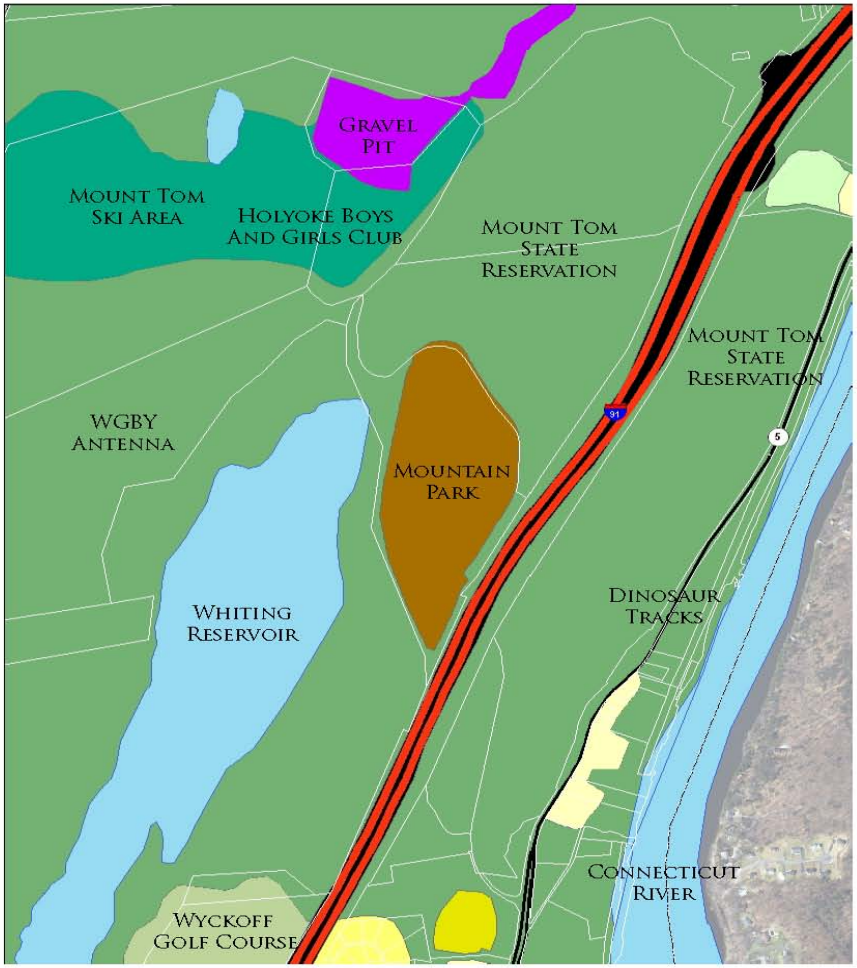
Figure 14: Zoning Around Mountain Park

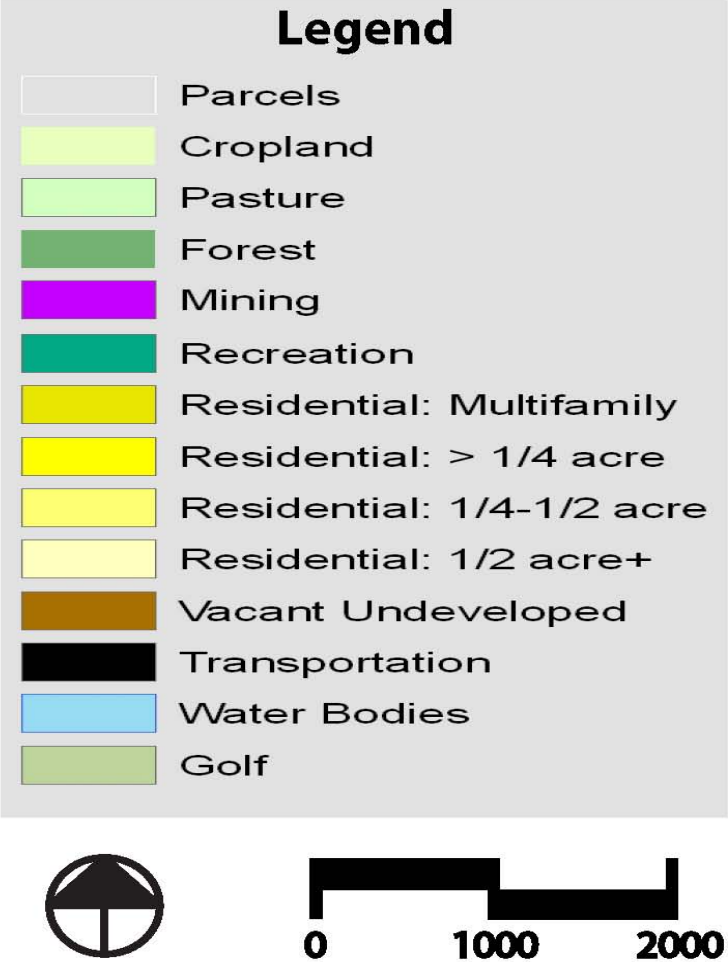




Source: MassGIS 2000, Matt Medeiros

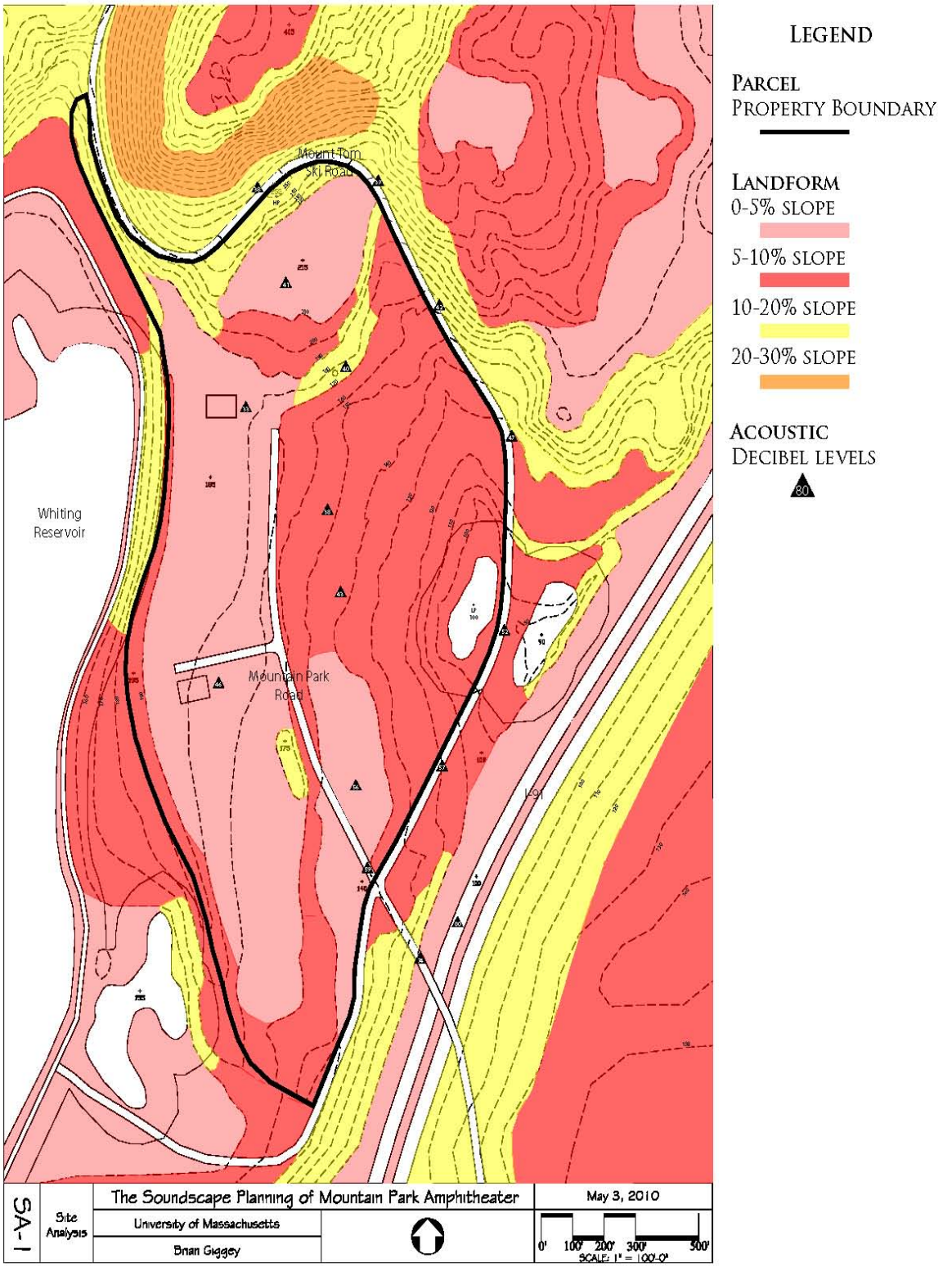
Figure 15: Land Use Around Mountain Park





Source: MassGIS 2000, Matt Medeiros

Figure 16: Landform and Acoustic Levels

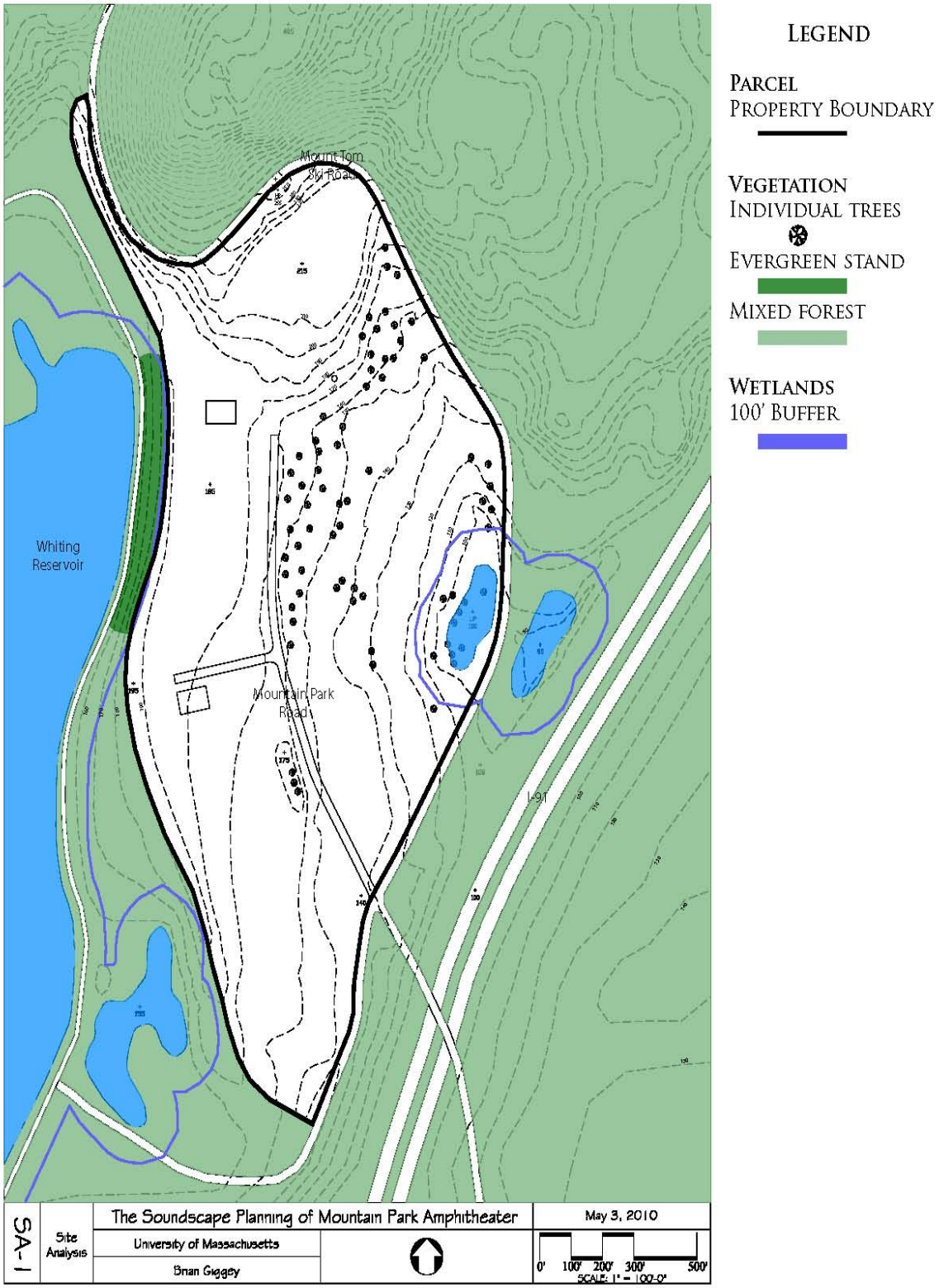


Although only one wetland sits on the Mountain Park site, there are two others that lie directly adjacent to it. These wetlands and the Whiting Reservoir have great educational opportunities since no development is permitted within the 100-foot setback regulations *(See Figure 17)*. The wetlands not only provide educational opportunities for visitors, but are habitat for wildlife as well. The on-site wetland should not affect development much, since it is located so close to the highway and is the lowest point of the site. In contrast, Whiting Reservoir's 100-foot buffer could possibly impinge on some development, since the parcel line is so close to the actual reservoir. Another concern regarding the Whiting Reservoir is the eutrophication that is occurring at its northern and southern ends. There is a smaller stream at the southern ends that feeds into the reservoir, carrying runoff from the fire road and adjacent golf course (Mount Tom Range Commission, 1993).

After a soil study, it was determined that the entire Mountain Park site is classified as Urban Land-Wethersfield-Paxton Association. This soil is extremely stony, sandy loam that has been disturbed by previous development. Although moderately permeable and susceptible to frost heaving, the City Council believes it has greater development potential than surrounding areas. The surrounding mountainsides are purely rock, while the buffer to the Whiting Reservoir is mostly sloping, rock outcroppings. South of the reservoir, the soils are primarily rocky, sandy loams and thus are not recommended for development. The majority of the soils in the surrounding context are classified as Rock Outcrop-Holyoke Complex, Steep. This classification is shallow depth to bedrock and is best suited for the woodlands that occupy it more so than any other use (Mount Tom Range Commission, 1993).

The reason for the high percentage of rock outcroppings are due to the fact that Mountain Park sits at the base of Little Mount Tom within the Mount Tom Range. Mount Tom is the highest peak of the Mount Tom Range and anchors the southern-most point. The mountain is composed of basalt, which is a volcanic rock usually termed traprock and was created by the volcanic eruptions that were the result of the separation of North America from Africa some 200 million years ago (Caffrey and Forbush, 2005).

Figure 17: Vegetation and Wetlands



Vegetation

With mature trees surrounding all sides of the site, high velocity winds are blocked from carrying through the site; paired with the drastic changes in elevation, sound already travels relatively well within the site. Running parallel to the interstate is mostly all deciduous plant material. Deciduous plant material is slightly inferior to coniferous plant material when it comes to attenuation of sound, so this area is only a mediocre buffer to the interstate. The deciduous plant material, comprised of mostly oaks, maples and elms will do a good job of cutting down on the noise pollution entering the site, but still could use additional heavy coniferous planting.

The mountainside surrounding the site is a heavy mix of deciduous and coniferous plant material, the latter of which is the best form of vegetative plantings in terms of sound attenuation. This strong mix of pine, spruce, maple, oak and elms, paired with large changes in elevation, will create a strong backdrop to the amphitheater not only visually, but acoustically. The strong pairing of vegetation and landform will cut down substantially on the sound leaving the boundaries of the site. There will be a good deal of sound that leaves the site, but with proper landform manipulation and vegetative plantings, the amount will be cut down drastically.

Running along the western border of the site, creating a buffer between the site and the Whiting Reservoir is mostly all deciduous plant material with spotted sections of evergreen plant material. Oaks, maples and elms make up the majority of the forest until reaching the northern section of the reservoir, where large groves on pine trees make up the entire forest. These groves of pines and other evergreen plant material act as a great buffer to the Whiting Reservoir, as this is the closest the reservoir gets to the site. This evergreen stand of the forest along the western edge of the site the rest of the way up to Mount Tom Ski Road, creating a semi-permeable visual and acoustic screen to the Whiting Reservoir *(See Figure 17)*.

Running along the western edge of Mount Tom Ski Road down to the on-site wetland is a swath of deciduous plant material that creates a strong edge to the eastern side of the site. This band of vegetation will create shade for users of the site as well as creating a buffer to sound leaving the site. The most substantial vegetation actually on site is the large shade grove located in the middle of the site. A combination of deciduous and coniferous plant material, the mix of spruce, oak, elm and beeches will create a

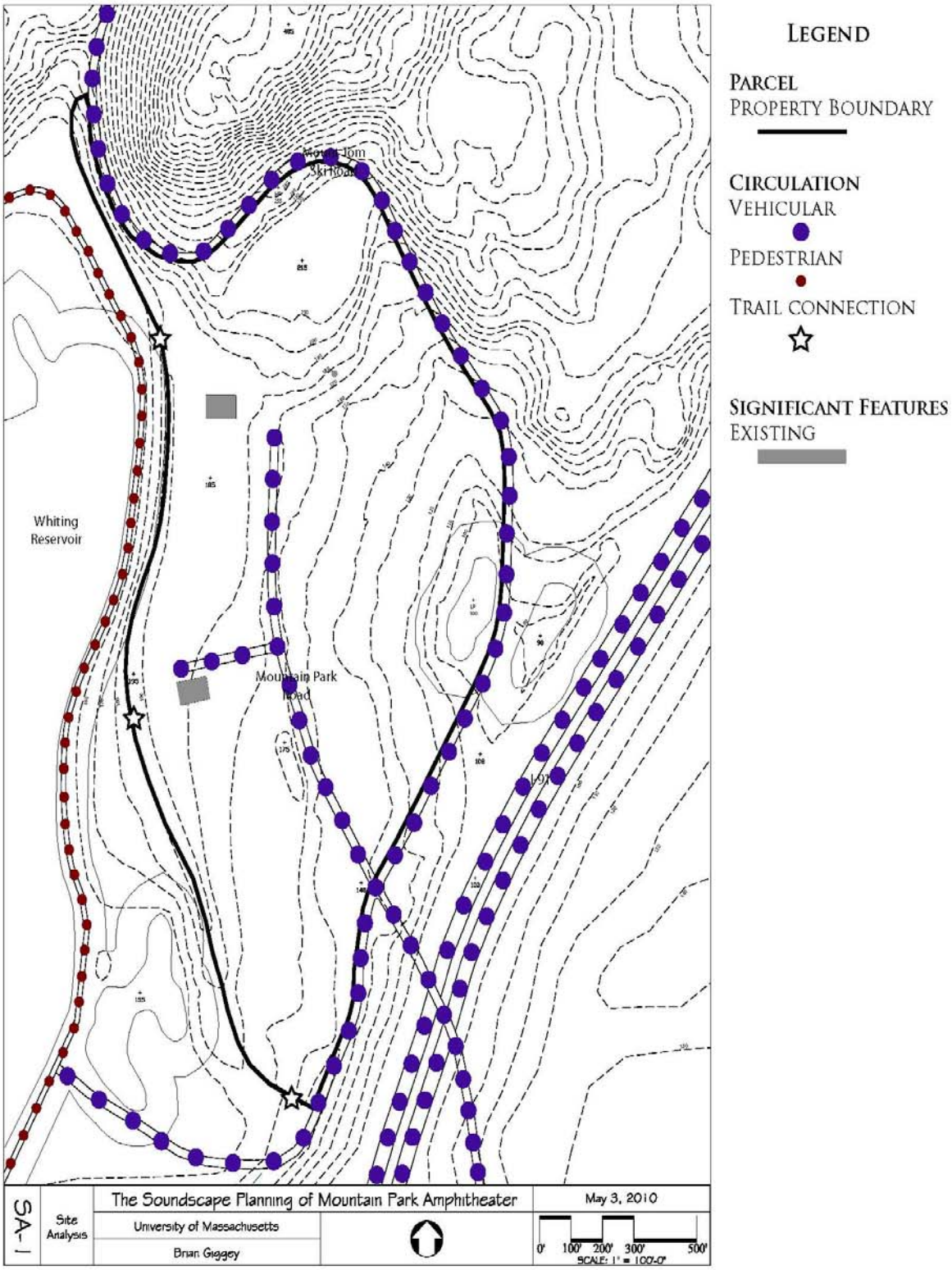
strong buffer to the amphitheater, as well as offering a place to meet friends and family before entering the amphitheater; also offering a nice spot for a picnic area. The mix of plant material will also aid in sound attenuation, minimizing the amount of noise leaving the site. The shade grove lines Mountain Park Road as it ties the upper portion of the site to the entrance of the park; nicely separating the useable open space from the large, flat areas that are better suited for parking.

Circulation

Connecting to Route 5, Mountain Park Road is the main vehicular connection to the site. After crossing the overpass, there is a paved access road, Mount Tom Ski Road, which runs along the eastern border of the site up to the highest point on the property. The road continues behind Little Mount Tom and provides access to a gravel yard that sits adjacent to Mountain Park Reservoir. This secondary road will provide access to the highest point on site, which will provide refuge from the performance. There is another road on site running directly south that links up to the Whiting Reservoir. Once over the overpass, Whiting Reservoir Road breaks off to the south where one reaches a gate, discouraging trespassers. The road links on to a gravel path that loops around the reservoir and eventually connects to Easthampton Road, which provides access to Easthampton and Holyoke from the north. The loop around the reservoir attracts a lot of runners and fisherman, even though fishing is discouraged in the reservoir.

Several running clubs can be seen meeting in the parking area of Mountain Park and using the loop for many of their meets. There are three access points from Mountain Park to the Whiting Reservoir loop; one is at the very southern portion of the site, another is in the middle of the site, directly adjacent to the existing open-air structure and the last is located at the northwestern portion of the site, where the trail comes very close to the property boundary *(See Figure 18)*. The walk from the entrance to the 60-acre Mountain Park parcel to the base of Little Mount Tom takes approximately five minutes; the walk through the woods from the entrance to the site to the Whiting Reservoir loop takes roughly three minutes.

Figure 18: Circulation and Significant Features



With beautiful views and plenty of recreational opportunities, residents of the Pioneer Valley continued to flock to Mountain Park, even when it was a vacant parcel. With dozens of hiking trails in the Mount Tom State Reservation just to the north of the site, hikers can link onto both locally and regionally-based trails systems. Several smaller trails that traverse existing canal systems and environmental art help connect the site to the Whiting Reservoir loop where one can link on to larger regional trails such as the Metacomet-Monadnock Trail and the Norwottuck Bike Trail. The owner of Mountain Park has been quoted as saying, 'the intent is for people to be able to utilize the property, even when they do not have a ticket to the performance' (Suher Interview, 2009).

Solar

With limited vegetation within the boundaries of the site, shade is rare at Mountain Park. The mountain range provides some shade in the morning while the sun is still climbing, but the western portion of the site receives sun early. The entire site receives persistent sunlight throughout the day as a result of limited structures and vegetation on site. Because of the Whiting Reservoir bordering the western portion of the site, a large portion of the site receives evening sunlight as well. The tall, mature forest buffering the reservoir from the site will cast shadows on the steep slopes of the upper portion of the site. This is beneficial due to the fact that the setting sun will not be in the eyes of the paying audience during show time.

Existing Features and Site Amenities

There are two existing features on site; an open-air structure and a large rock *(See Figure 18)*. The open-air structure is located in the flat, large open space with an access road connecting it to Mountain Park Road. The structure is completely made of metal with four legs on each side resting on concrete footings. Before being relocated, the structure was resting on a large concrete pad at the northern terminus of Mountain Park Road. This 100-foot wide by 60-foot long concrete pad is still intact and can be used to house the main portion of the amphitheater, but is recommended that it be removed. The other existing feature on site is a large rock by the shade grove that was once a popular meeting spot for the Northampton-bound trolley. The rock is located in the middle of the

steep slope that faces the onsite wetland so it can be used as a gathering space or viewing point to take in views of the site and its surrounding context.

The existing onsite structure has now been relocated to the central portion of the flat parking area. This structure can act as a parking/vending permit station as well as holding concessions and restrooms. Parking permits will be given to patrons parking in the VIP lot, which holds a total of 300 cars. The largest portion of the parking lot will be free parking, holding 1,400 cars. The furthest parking spaces from the amphitheater will be given to employees, enough space to hold 30 cars. Across Mountain Park Road will be the overflow parking area, which can accommodate 225 cars. This lot, which will double as a vending/temporary attractions space during large performances, is a two-minute walk to and from the amphitheater.

The Mountain Park site already has water, gas and electricity access on site. There are currently utility poles lining both sides of Mountain Park Road, but wires are then buried between the end of the roadway and Mount Tom Ski Road. The power lines are day lighted again at Mount Tom Ski Road and continue along utility poles around the back side of Little Mount Tom. Also worth noting are the gates that are located at the main entrance to the site. Permanent gates are located at the beginning of Mount Tom Ski Road and Whiting Reservoir Road, while a temporary fence has been installed across Mountain Park Road to keep any traffic from driving into the site.

Acoustic Conditions

The most important land use impact in close proximity to the site is Interstate 91, which borders Mountain Park to the southeast. The four-lane highway is divided by a small median and is buffered heavily to the southeastern side by steep landform and dense vegetation. The northwestern border of the highway is buffered substantially less and thus poses a problem in terms of the noise pollution that could affect the concert experience at Mountain Park.

There is a large grade change along the northwestern border of the highway which borders Mountain Park, as the steep landform starting at the overpass slowly turns into a gentle slope that meets a wetland that sits at the very edge of the site. The grade change between the highway and the top of the landform buffer that borders the southeastern side of the interstate is 25 feet, while the grade change on the northwestern side of the

interstate varies substantially. There is a grade change of roughly 20 feet between the highway and where the overpass meets grade on the northwestern side of the interstate. As one moves to the northeast just off the site, the landform buffer decreases as it slopes down to an offsite wetland. There is still a grade change of roughly five feet between the highway and the top of the landform buffer that borders the northwestern side of the interstate, before sloping drastically down to the wetland that is in between the interstate and Mount Tom Ski Road.

The interstate creates varying degrees of noise pollution depending on where you are standing within the site *(See Figure 16)*. When standing on the shoulder of the interstate, the decibel level reading is 80 decibels. Located 11 feet in the air along the overpass to the site, the reading is 74 decibels. When standing at the entrance to the site, the noise of the interstate is substantially less, registering 59 decibels. The steep slope of the embankment has a drastic impact, as the decrease of 21 decibels occurs over a span of 300 feet. Two more readings were taken along Mount Tom Ski Road, with varying degrees of attenuation. The first reading was taken 400 feet away from the entrance, buffered by landform and vegetation from the highway, giving a reading of 57 decibels. Down by the wetlands, buffered by landform and vegetation, but five feet lower in elevation than the highway, a reading of 52 decibels was registered. These two substantially different readings are attributed to the fact that sound waves travel upward. After reflecting off the landform and vegetation, the noise pollution from the interstate travels uphill to the back portion of the site, which will be seen in the following decibel level readings.

As one works one's way up Mountain Park Road, the visual and acoustic impact of the highway becomes less and less. The overflow parking lot registered a level of 56 decibels, while the reading taken at the existing structure in the middle of the parking lot was 46 decibels. As predicted, the shade grove proved to be a large contributor to the attenuation of sound, as the beginning of the shade grove had a reading of 42 decibels, the middle at 38 decibels and 33 decibels at the end. The reading of 33 decibels at the end of the shade grove is where the amphitheater will be located as this is the quietest place on the entire site, with a substantial vegetative buffer between the performance space and the interstate.

Proving that sound attenuation is not linear with distance, the decibel reading at the existing rock located next to the shade grove was 40 decibels. The reading at the upper plaza was 41 decibels and then lastly, the reading at the base of Little Mount Tom on Mount Tom Ski Road was 38 decibels. With two out of the three readings higher than some locations closer to the interstate, it shows that distance from the source is not linear, nor is it the main factor in sound attenuation. Elevation change as well as landform and vegetative buffers between the source are the main factor for sound attenuation.

Land Uses and Zoning

Due to the nature of the past use of Mountain Park and its proximity to Interstate 91, the 60-acre parcel falls under the designation of Business Highway. This zone is intended for uses such as service stations and fast food restaurants, which is why the city of Holyoke recommends establishing a zoning overlay ordinance for this area, such as a Planned Recreation District. This district requires a minimum lot size of 10,000 square feet and a maximum coverage of 50% (Holyoke Planning Department, 2005). The city of Holyoke was concerned with the business highway designation for Mountain Park and thought that a Planned Recreational Zone should be researched in order to promote recreational uses while still providing control of the ecological habitat that surrounds it (Mount Tom Range Commission, 1993). If an overlay zone is to be implemented, the amendment must be approved by the Holyoke City Council.

The majority of the area surrounding Mountain Park is zoned as RA, agriculture and single-family residential. This is Holyoke's least intensive district as far as density and lot size, with a minimum lot size of 20,000 square feet and a maximum coverage of 20% (Holyoke Planning Department, 2005). Its primary function is to encourage single-family homes and agricultural usage, and to protect water resource areas including aquifers and public reservoir watersheds.

The land along the Connecticut River is zoned for single family residential, which is the next largest type of zoning. The quarter acre (11,250 square feet) minimum lot size encourages the typical suburban subdivision, and fits well along Route 5, the main connection between the cities of Holyoke and Northampton. Single-family residential zoning regulations include 90 feet of frontage and a maximum coverage of 30% (Holyoke Planning Department, 2005).

The remaining zones in close proximity to the site are RM20, which is the least dense multi-family district in Holyoke at 20 units per acre. Although the minimum lot size is 6,000 square feet, it does require at least one acre for initial development (Mount Tom Range Commission, 1993). These parcels have a maximum coverage of 40% and are found in two areas. The first is directly south of Mountain Park, at Castle Hill Condominiums, which is now currently owned by Mr. Suher, and the second is a residential cluster just to the northeast of Mountain Park, situated along Route 5 on a sloping hillside offering breathtaking views of the Connecticut River.

Public open space is the dominant land use around Mountain Park, as the Mount Tom State Reservation borders Mountain Park to the north and east. The Holyoke Water Department has protected mostly all the open space to the west of the site, as the Whiting Reservoir occupies most of this land. Outdoor recreation is the second largest land use, with the Mount Tom Ski Area and Holyoke Boys and Girls Club bordering the site to the northwest, Wyckoff Golf Course to the southwest and Holyoke Country Club to the northeast of Mountain Park. Residential land use comprises a very small portion around the site, but is still worth noting due the effect of the concert acoustics on them. The residential land use includes single, two, and multi-family residences, with single family residences making up the majority of the category. The last land use in close proximity to Mountain Park is industrial, and is located just to the north of Mountain Park on the back side of Little Mount Tom; this industrial designation is a gravel pit that is owned by Daniel O'Connell's Sons, Inc.

With its location in the Mount Tom Range, the land surrounding Mountain Park is priority habitat for a handful of endangered species. The Massachusetts Natural Heritage and Endangered Species Program have called Mount Tom "one of the most important and ecologically significant rare species localities within the Commonwealth" (Mount Tom Range Commission, 1993). The Mount Tom Range is extremely important to many migratory birds because of its location within the Mount Holyoke Range and close proximity to the Connecticut River and Whiting Reservoir.

Site Analysis Discussion

Situated between multiple residential land uses and in close proximity to the interstate, Mountain Park has the challenge of not only mitigating off-site noise pollution,

but enhancing on-site acoustics and minimizing effects on surrounding land uses. A composite site analysis was compiled, showing that Mountain Park is ready for development of an amphitheater, which will not only take advantage of the on-site amenities, but provide views and connections onto the surrounding context *(See Figure 19)*.

The landform and vegetative buffers around the site provide a great opportunity for mitigation of noise pollution from both entering and exiting the site. The steep slopes along the interstate diminish a substantial amount of noise from entering the site, and the flat open space in close proximity to Mount Tom Ski Road provides the opportunity to heavily buffer the edge of the site, mitigating as much noise pollution from entering the site, as soon as possible. The evergreen mixed forest surrounding the site will help attenuate sound, while the evergreen stand between the reservoir and stage area will not only create a single-color, unbroken backdrop to the stage, but quickly attenuate the majority of sound from reaching the water body.

Vehicular circulation to and from the site in the form of Mountain Park Road is a huge advantage, as the road terminates on site. This will provide the opportunity to turn the road into a two-lane, one-way road, easing the exiting process and the ability to give priority exiting to the band and VIP patrons. The pedestrian circulation around the site is also an added benefit for Mountain Park. The pedestrian loop around Whiting Reservoir, as well as the trail system through the woods adjacent to the parcel and above Little Mount Tom provides an extensive amount of possible connections.

The close proximity of the interstate and Whiting Reservoir to Mountain Park, paired with the uphill gradient of the site, provides a great opportunity to showcase high quality soundscape planning *(See Figure 20)*. With residential land uses nearby, proper location of the amphitheater along with heavy landform and vegetative buffering must be implemented to reduce the impacts of the performance. Interstate 91 will always have an impact on Mountain Park, but proper design can alleviate some of the problems that could influence the success of the performance space.

Figure 19: Composite Site Analysis

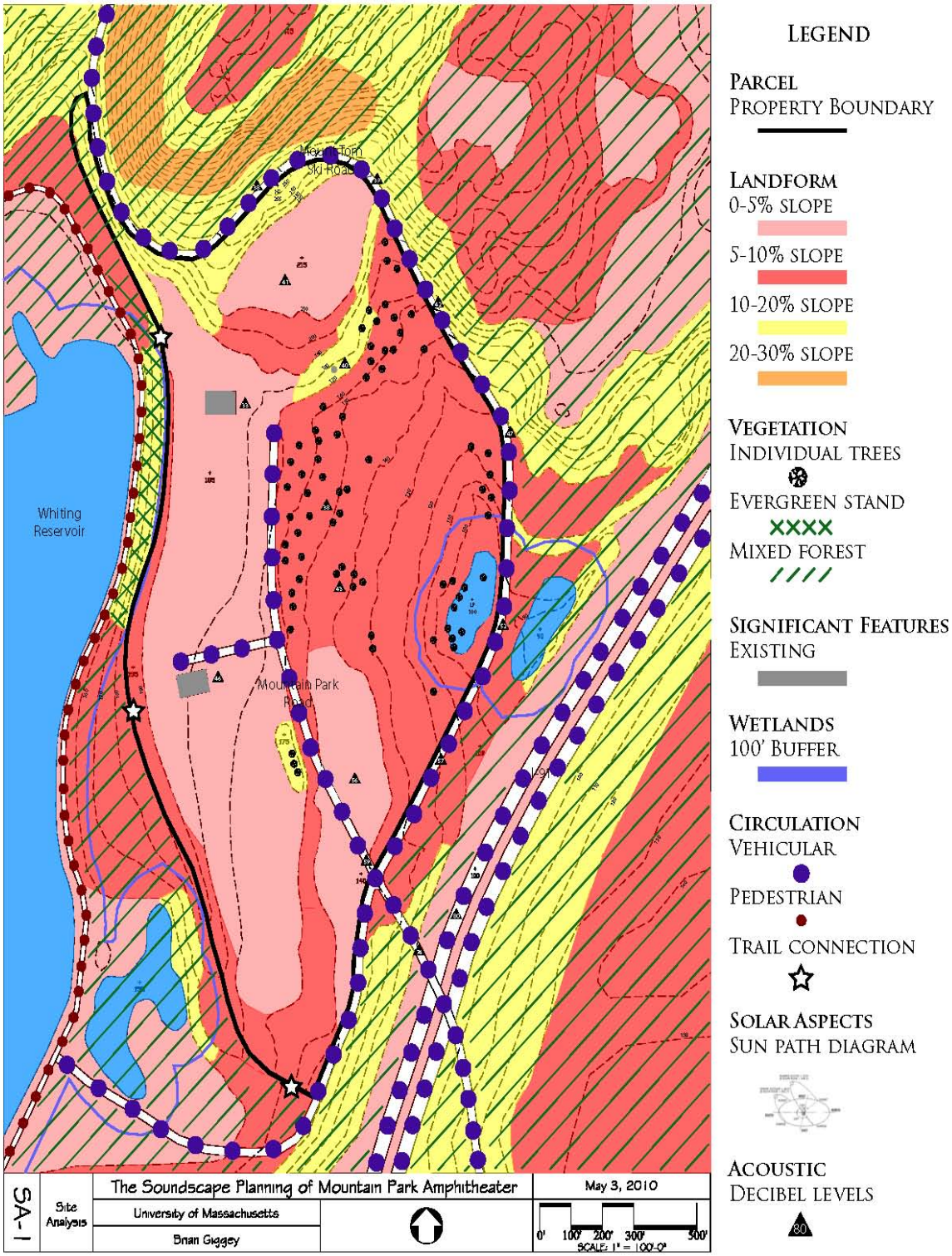
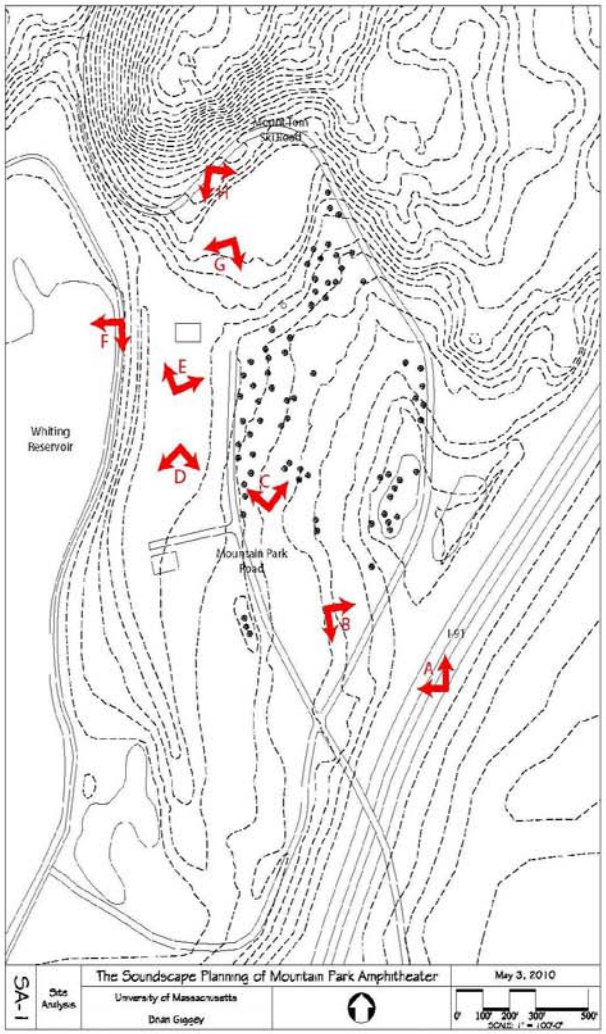


Figure 20: Intervisibility Map of Mountain Park



View A: Looking into the site from Interstate 91

View B: Looking out from the site to Interstate 91

View C: Looking uphill to the shade grove

View D: Looking at the existing structure and large parking area

View E: Looking up to Little Mount Tom; shade grove is on the right

View F: Looking at the pedestrian loop around Whiting Reservoir

View G: Looking over stage area, shade grove and Whiting Reservoir

View H: Looking over the site from Mount Tom Ski Road

DESIGN PROPOSALS AND RECOMMENDATIONS

5.1 – Overview

The ultimate goal of this project was to create a conceptual master plan for a 7,000-person amphitheater at Mountain Park. Based on extensive research in soundscape planning and amphitheater design, a master plan and supporting graphics were created *(See Figures 21 and 22)*. With its prime location within a secondary music market and its operation under the direction of Iron Horse Entertainment Group, Mountain Park has the opportunity to flourish as 'New England's Finest Amphitheater.'

Mountain Park is situated in close proximity to the Whiting Reservoir and a wide range of trails that run through the Mount Tom State Reservation and beyond. Offering views of the reservoir and South Hadley from the top of the site, patrons can let their eyes wander over the landscape, extending their sense of place far beyond the confines of the site. Mountain Park still houses the shade grove that was so wildly popular back during the first half of the 20th century, as well as a large rock in the center of the site, which provides the opportunity for climbing and enjoying views all over the site as well as of the performance area.

Taking advantage of the entire site, the design of Mountain Park provides superior acoustics, circulation, and vantage points. Quickly gathering incoming vehicular traffic, the heavily buffered parking lot is secluded from the rest of the site, while pedestrian walkways on all sides provide connectivity through the entire site, offering connections to the shade grove, amphitheater, and Whiting Reservoir trail system. Landform and vegetative buffers are constructed along the periphery of the site, mitigating offsite noise pollution as soon as possible, while buffers along Mountain Park Road up to the amphitheater help keep parking and vehicular noise to a minimum.

The amphitheater sits at the terminus of Mountain Park Road, taking advantage of the existing infrastructure of the site. The amphitheater is oriented such that sound is directed into the face of Little Mount Tom, substantially reducing the amount of noise leaving the site and having adverse affects on surrounding land uses. Steep landform and a heavily planted northern edge of the site help mitigate as much sound from leaving the site as possible. With beautiful views of the Whiting Reservoir, South Hadley, Holyoke, and Springfield in the distance, the design of Mountain Park provides a large gathering

space at the highest point of the site. Located 165 feet above Interstate 91, the highest point on site is 30 feet above stage level and 190 feet below the top of Little Mount Tom. This area provides a meeting and gathering space outside the performance area, which is ideal in amphitheater design, especially while able to reveal such views as those provided at Mountain Park. Directly connected to the performance space itself, the upper plaza provides refuge from the concert experience while providing superior acoustics to patrons wishing to view the performance from the top of the site. Connections to the promenade, shade grove, and camping area are also provided through pedestrian pathways that connect directly to the amphitheater. Strong circulation throughout the design of Mountain Park helps patrons take advantage of the entire site, while strong landform and vegetative buffers help mitigate on and offsite noise pollution, enhancing the acoustics of the performance within the amphitheater.

The conceptual master plan of Mountain Park is a demonstration of the research conducted and should be used in conjunction with a professional landscape architect and acoustic engineer. The location and specifications of the venue, parking, and vegetative buffers are accurate, but should not stand alone. These recommendations achieve two goals: 1) mitigate the offsite noise pollution and lessen impacts on surrounding land uses; and 2) enhance the acoustics within the space. The design, orientation and location of the amphitheater is the best-case scenario for the site based on the research and site analysis conducted for this project, but is recommended that design professionals should be brought in for consultation and the construction aspect of the design.

Figure 21: Master Plan of Mountain Park

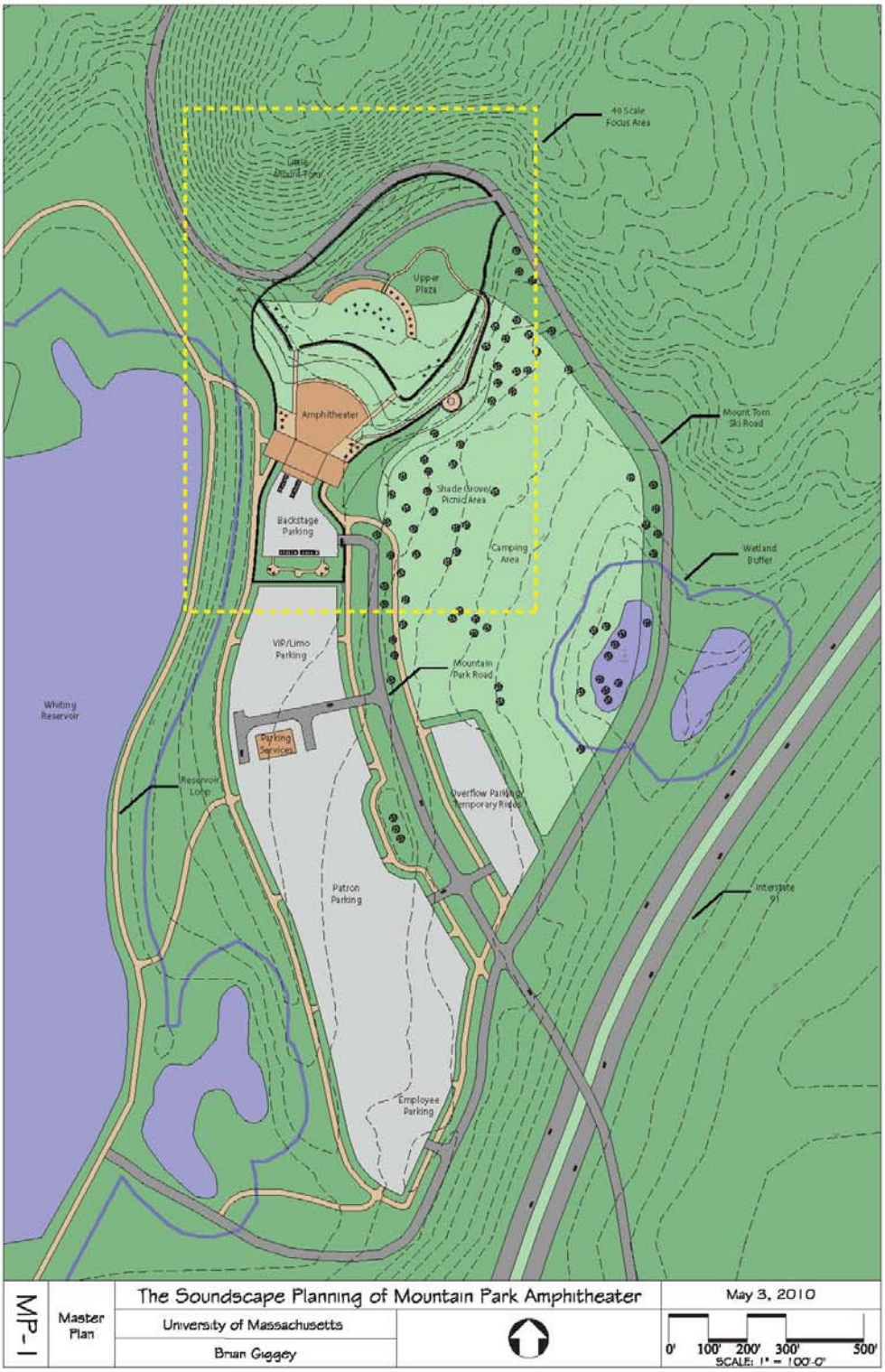
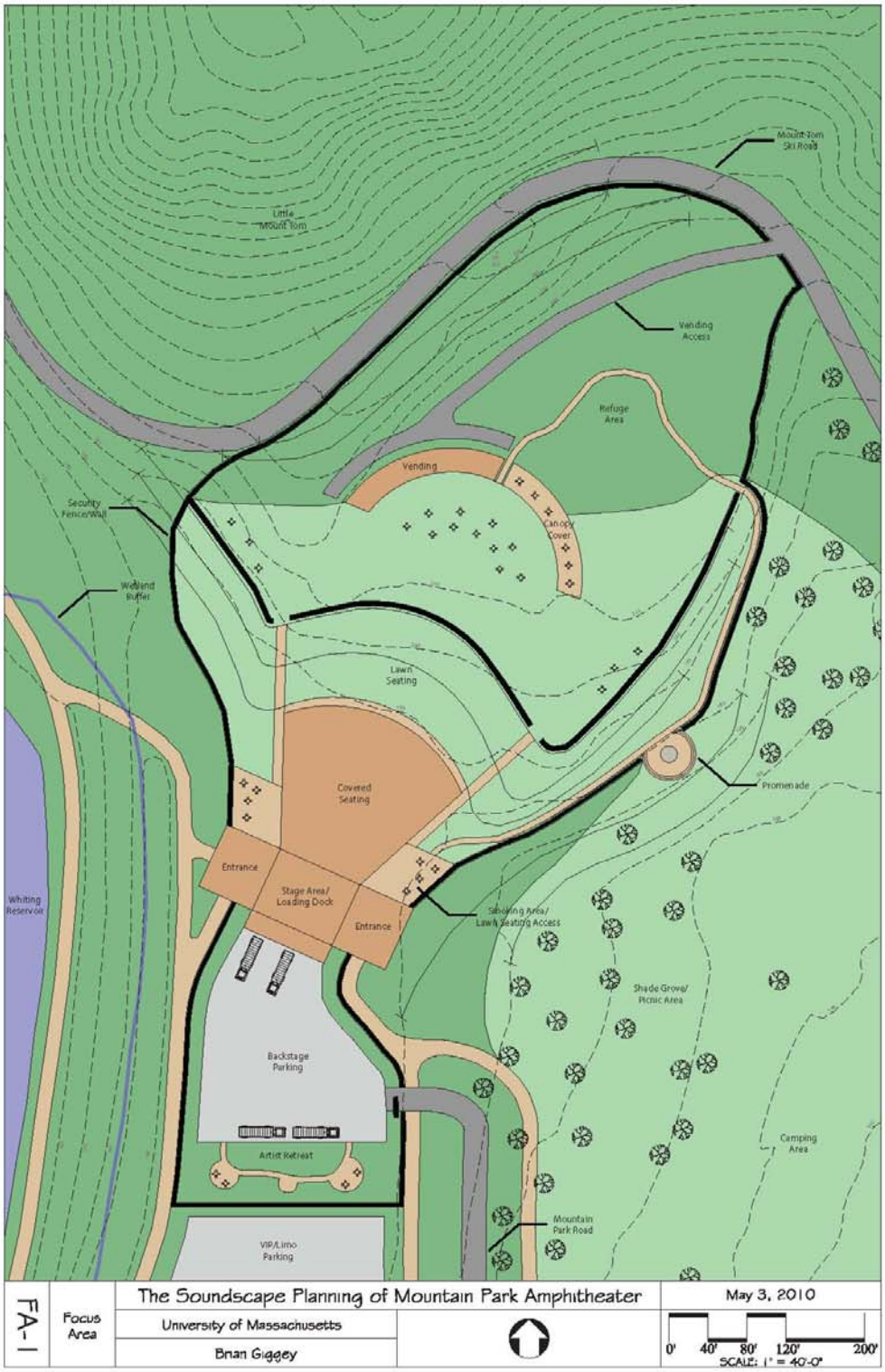


Figure 22: Focus Area Plan of Mountain Park



5.2 – Conceptual Design

Interstate 91 generates significant noise pollution; from an acoustic perspective, it is a predominate factor in the design of Mountain Park. Registering 80 decibels on the shoulder of the interstate, the sound of the highway can be heard from every corner of the 60-acre parcel. To help gain a better understanding of the noise pollution on site, decibel levels were taken at multiple locations, helping determine the best acoustic location for the amphitheater. In conjunction with the testing of decibel levels, a detailed site analysis on landform, vegetation, existing significant features, wetlands, circulation, solar aspects, and views was conducted.

Along with the acoustic research conducted, the site analysis quickly brought the location of the amphitheater, in relation to its parking and areas for buffering, to the forefront. With steep grade changes and vegetation bordering the interstate, Mountain Park has a strong foundation for mitigation of offsite noise pollution. Within the 60 acre parcel the majority of the vegetation is located within the central portion of the site, leaving the opportunity to significantly buffer the interstate with landform and vegetation. A 45-foot buffer of landform and vegetation has been proposed around the entire periphery of the site, buffering not only traffic along Mountain Park Road and Mount Tom Ski Road, but the noise from Interstate 91 as well.

Before a thorough site analysis was conducted, one other possible location of the amphitheater presented itself. Situated in the central portion of the site, with Mountain Park Road to the east and the shade grove to the east, and Mount Tom Ski Road running up the western border, the amphitheater would be directed to the highest point of the site, using the shade grove and Little Mount Tom to buffer sound from reaching the Whiting Reservoir and any surrounding land uses. Access to the backstage area would come from Mount Tom Ski Road, but would have been severally limited due to the on site wetland and its buffer restrictions. A handful of large trees and the existing rock on site would have been located directly in the middle of the lawn seating area and would have been removed; the historical significance of the existing rock was unknown at the time. After a through site analysis and the obvious fact that there was very little buffer between the interstate and proposed location of the amphitheater, this area was ruled out as a potential location.

With landform and vegetative buffering lining both sides of Mountain Park Road up to the amphitheater, noise from vehicles and parking are kept separate from the performance and gathering portion of the site. Pedestrian circulation is buffered from the road as multiple pathways lead up to the amphitheater which is situated directly adjacent to the shade grove that was popular in the first half of the 20th century. The shade grove, consisting of a mix of both evergreen and deciduous plant material, is a strong buffer to the interstate, as the proposed location of the amphitheater on the other side of the shade grove is the quietest place on site, registering 33 decibels, levels equivalent to that of a conversation.

Pedestrian circulation runs along both sides of Mountain Park Road as well as along all sides of the larger parking area *(See Figure 27)*. This form of circulation offers the opportunity to either go to the amphitheater, to the middle of the site or to walk along the wooded edge of the site with linkages to the Whiting Reservoir loop and surrounding trail systems. There is a 15-foot wide landform and vegetative buffer that separates the pedestrian circulation from the parking, with a 45-foot landform and vegetative buffer separating the pedestrian circulation from the vehicular circulation of the site *(See Figure 25)*.

The guest experience starts with a walk along the path leading uphill to the amphitheater. The uphill gradient of the site lends itself to a feeling of anticipation as more and more of the amphitheater is slowly revealed as one gets closer. One can see how the amphitheater is oriented towards Little Mount Tom with its steep rock face and mix of evergreen and deciduous plant material, which acts as the backdrop to the entire performance space. Still along the pathway, one can also see through parts of the shade grove to the promenade, with kids climbing on the existing rock as the extended lawn is scattered with concert-goers taking in the views of South Hadley while they wait for the performance to begin. As patrons get closer to the amphitheater, excitement really begins to build as they can see the actual lawn portion of the venue beginning to fill up with couples on blankets and dancers spinning in the sunshine to house music played over the PA system. Eager fans lurk near the gate to the backstage area in hopes that they catch a glimpse of their favorite performer, while streams of people walk the pathway along the eastern portion of the property down to the Whiting Reservoir, passing time before the performance begins.

Wing buildings on either side of the stage house block views into the covered seating portion of the venue, situated at the base of the existing 15% slope on site. The amphitheater is oriented north to south with its sound directed into the face of Little Mount Tom *(See Figure 28)*. North to south orientation is optimal for amphitheaters, with the audience sitting on the southern end of the venue. Due to the limitations given by the topography of the site, the audience is situated at the northern end at Mountain Park. East to west orientation of an amphitheater, with the audience seated on the eastern end, is the worst possible orientation as the setting sun falls directly in the eyes of the audience. The natural formation of the land at Mountain Park lends itself to an amphitheater, locating the audience at nearly the highest point on site, where beautiful views are offered into the surrounding landscape.

The existing concrete pad that is located at the proposed location of the amphitheater crosses over into a portion of the stage house and covered seating area and can be reused if need be, but this plan recommends that it be removed. The covered structure of the amphitheater sits on a slight uphill grade and will be re-graded to a 5% slope. This 5% slope will allow the audience to have unobstructed sightlines of the stage while maintaining handicap access without the use of handrails. The covered structure of the amphitheater will include the audience seating area and stage house, with wing entrances and smoking areas. The wing entrances will accommodate bathrooms, merchandise, ticketing, and a portion of the concessions as well as educational displays about the history of Mountain Park and how the soundscape design of the new site came to be. Reserved ticket holders can enter the covered seating area directly, while general admission ticket holders on the lawn must go through the outdoor smoking/vending area to get to their seats. The alternate entrance to the lawn seating discourages general admission ticket holders from gaining access to the higher-priced, reserved seating of the performance. The outdoor smoking/vending area will provide patrons a break from the performance while offering a chance to visit the concessions without exiting the performance space *(See Figure 29)*.

As patrons pass through the entrance, the venue begins to unfold as the stage is set with an expansive light system and ushers are ready to show patrons to their seats. As they are ushered to their seats, the view up to the lawn is less than 150 feet away. The steep face of the lush lawn makes those under the covered structure feel a heightened

sense of intimacy. Those located on the lawn, soon to be filled with 5000+ concert-goers also feel a similar sense of intimacy and enclosure, as Little Mount Tom soaring in the background helps define not only the performance space, but the Mountain Park site as a whole. The existing grade of the lawn area will be re-graded from 15% to 25%, the optimal slope of an amphitheater for viewing a performance *(See Figure 24)*. The audience on the lawn can see the performance from the stage directly or may watch on the large video screens that are situated along the façade of the covered structure.

With its captivating views on both sides of the amphitheater, the design of Mountain Park offers extended lawn seating, a design element used at popular venues like Alpine Music Valley in East Troy, WI. Extended lawn seating offers views of the performance while offering views of the offsite vistas. When seated in the regular lawn seating area, there are minimal offsite views as the main attraction is the performance itself. The evergreen trees in the background act as the perfect backdrop to the stage as its continuous screen and color create a 'wall' that attracts no attention and buffers sound extremely well. Extended lawn seating areas on both sides of the venue offer views of either the Whiting Reservoir or South Hadley. Since extended lawn seating areas are secondary uses within a performance space, the lawn can be graded in any particular fashion. Popular at world-renowned venues such as The Gorge Amphitheater in George, Washington, landform seating can be implemented here. The lawn can be re-graded to have a stepped down look, naturally fitting to the human body. Grade of the regular lawn seating is conducive to looking at the stars, while landform seating in some areas of the extended lawn area can give a backrest to those who want to take in the views of the sites in a seated position. Still located within the cone of sound that is coming from the stage, patrons will still be able to enjoy the high-quality acoustics of the performance while taking in the views of the adjacent land uses.

Directly in connection with the performance space is the upper plaza, a large gathering space to the north which offers a place to meet friends, visit the concessions, or take in the views of the surrounding landscape from the highest point on site. A four-foot high wall helps separate the upper plaza from the lawn seating, offering a place for patrons to rest against, sit on, or eat from. The wall around the upper plaza connects to taller walls around the periphery of the venue, helping keep out non-paying visitors. The wall is kept low within the performance space to help give definition, maintaining a low

enough height to provide views over, while it becomes taller in areas along the roadway and backstage where security won't be positioned.

The upper plaza at Mountain Park is an additional benefit, since many venues do not provide a meeting space within the venue. Most gathering and meeting spaces are provided at the entrance, in transition from the parking lot to the performance space. Mountain Park provides the opportunity for patrons to wait for friends while viewing the performance, as the upper plaza is in direct connection to the entrance and stage area via a number of pedestrian pathways. The upper plaza, with its superior acoustics, is divided into two different sections; the front section is the main gathering space where friends can meet, use the concession stands, and view the performance, while the back section acts as a refuge area. While located within the front portion of the upper plaza, views of the performance are maintained, as well as views of the Whiting Reservoir and South Hadley. The concessions and canopy-covered seating area attract patrons to the top of the site, offering a place for those to enjoy their food *(See Figure 30).*

The semicircle of concessions and canopy-covered seating helps define the outer edge of the performance space, creating a separation from the refuge area. The entire upper plaza area is planted with grass like the lawn seating area, while the refuge area in the back is highly vegetated, helping to mitigate the sound leaving the site as well as providing shade and an alternative experience to the performance. Successful venues such as Saratoga Performing Arts Center have expansive refuge areas located far from the performance, offering a place to lay out a blanket under the tree canopy, take a nap, or hang a hammock. A variety of alternative seating and gathering areas are provided at Mountain Park, offering patrons multiple ways of experiencing the performance.

Handicapped access to the upper plaza, concessions and refuge area is also provided along a wall-lined pathway that takes patrons through another extended lawn seating area to the promenade located at the existing rock in the center of the site. This path connects the upper plaza to the entrance of the amphitheater, providing access to the promenade and center of the site along the way. The promenade is a wooden deck that circles around the large existing rock, which offers a gathering space and an obstacle to climb on. The promenade and extended lawn seating area provide another viewing point of the performance, but the primary focus of these is to provide a space to take in the views over the site into South Hadley. The promenade is the main connection between

the performance space and the central portion of the site as it steps down to the existing grade and allows access to the center of the site where patrons can come and go between the performance and shade grove, picnic area and camping areas *(See Figure 26)*.

Located directly adjacent to the amphitheater, the shade grove is interspersed with a mixture of mature evergreen and deciduous plant material, providing a strong buffer to the interstate and vehicular traffic on site. The structure of the amphitheater, vegetation of the shade grove and sloping landform helps define the large open space in the center of the site, which slopes slightly downhill to an onsite wetland adjacent to Mount Tom Ski Road. This large open space will remain undeveloped and will enjoy enhanced acoustics as landform and vegetative buffers will run on all sides, mitigating any on or offsite noise pollution from entering the center of the site where many will play, relax and camp. This large area, still in connection to the amphitheater via the promenade by the existing rock, will provide a space for recreation as well. The shade grove, with several picnic tables scattered throughout, will act as the refuge area within the open space. Users of the site that do not wish to attend the performance can enjoy the site in a completely different fashion, while still hearing the performance clearly.

The 45-foot buffer that runs along the periphery of the site along Mount Tom Ski Road will help mitigate noise from Interstate 91 from entering the site *(See Figure 23)*. Mountain Park Road, which provides access from Route 5 all the way up through the middle of the site to the amphitheater, will also have the same buffer treatment, mitigating traffic and parking noise from entering the open and performance spaces of the site. This buffering treatment to the edge of the site as well as Mountain Park Road and the large parking areas, will not only help mitigate offsite noise pollution, but will enhance acoustics of the site as well; the sounds of leaves rustling, birds chirping, and water trickling.

With Mountain Park Road bisecting the southern and central portion of the site, there are multiple chances to turnoff into the parking areas located on both sides of the road. Mountain Park is the only land use along Mountain Park Road, which is an advantage when designing the exiting vehicular circulation of a heavily attended performance. Parking cones can line the middle of the road, effectively turning Mountain Park Road into a two-lane, one-way road. This will allow a lane for the bands and VIP

parking to exit quickly before other patrons do, as well as alleviating some of the overall stress of exiting a full parking lot.

The parking situation at Mountain Park is rather simple, holding a total of 1,965 cars. Mountain Park Road terminates at the backstage parking area, which totals 32,000 square feet. This area can hold 125 vehicles, but is more suitable for tour buses, tractor trailers, vending trucks and staging gear. Located to the south, directly connected to the parking area, is a green space known as the artist retreat. Seldom do bands and tour bus drivers have a place to relax privately in the outdoors; they are often rushed into the venue where they have a generic backstage green room with couches, televisions, and catering. A shaded outdoor space with hammocks tied between trees, picnic tables, and outdoor gathering spaces is an amenity that few performance venues take the time to implement. Completely surrounded by a fence, the artist retreat and backstage parking area is isolated from the general public, offering privacy and solitude.

Adjacent to the backstage parking area, closest in proximity to the venue, is the VIP/limousine parking. This is an area of 75,000 square feet and holds 300 vehicles. This parking area will offer patrons a shorter walk to the venue and a quicker exit from the performance, as well as providing some extra revenue for the venue. VIP parking costs are usually in the $20-30 per vehicle range, with limousines attracting a price tag of $50-100. The largest parking area on site is the free parking which totals 350,000 square feet, holding 1,400 vehicles. There are three access points to the free parking area, offering multiple exiting points after the performance. The main entrance to the parking area is near the top of Mountain Park Road where the road breaks off to go up to the existing open-air structure. This structure can house restrooms, but mainly will be used for concessions and distribution of vending and VIP parking permits. Employee parking is located at the furthest point from the venue, totaling 8,000 square feet and holding 30 cars. Across Mountain Park Road is an overflow parking lot that can be used for parking or housing of temporary vending and amusement park rides during large events. This area is 55,000 square feet and can hold 225 vehicles. The importance of parking on both sides of the street with multiple access points cannot be stressed enough. Turning Mountain Park Road into a two-lane, one-way road will alleviate much of the stress of exiting the performance, giving patrons a lasting, positive experience of Mountain Park as they leave the site.

Figures 23-26: Sections of Mountain Park

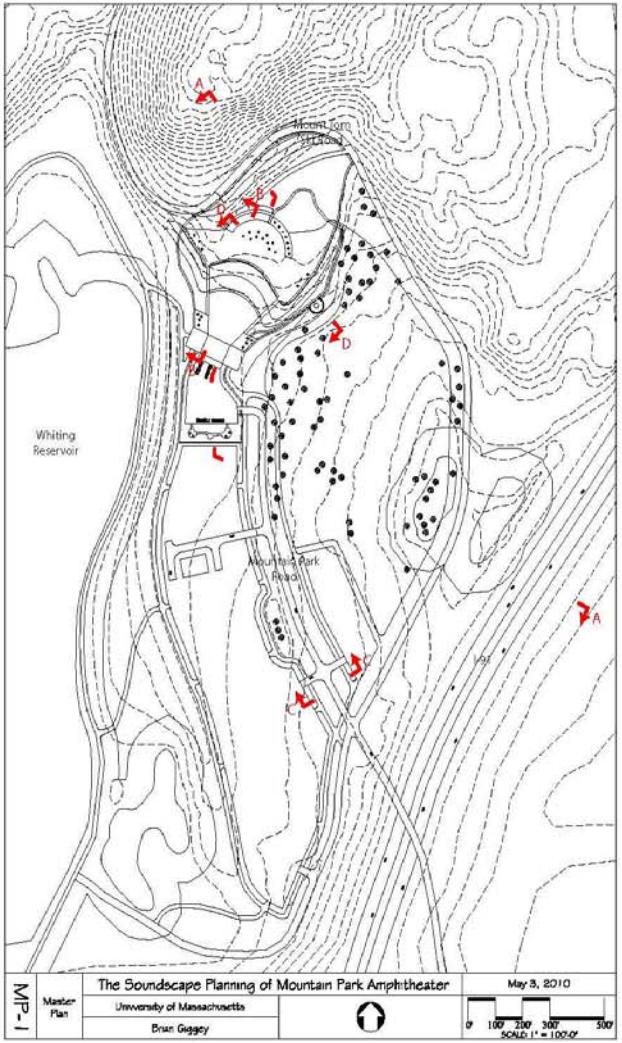


Figure 23: Section A-A shows the relationship of the amphitheater to Interstate 91

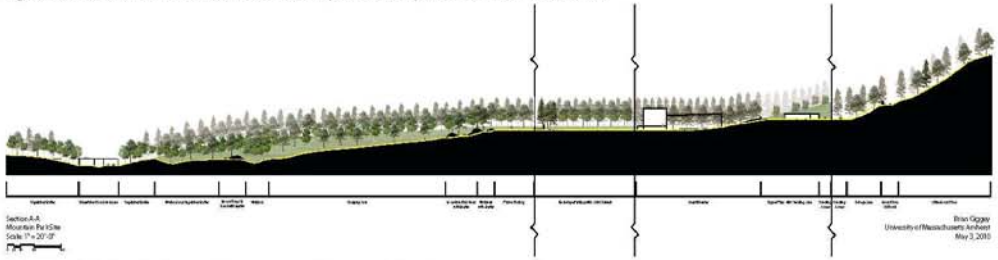


Figure 24: Section B-B shows the design of the amphitheater and upper plaza

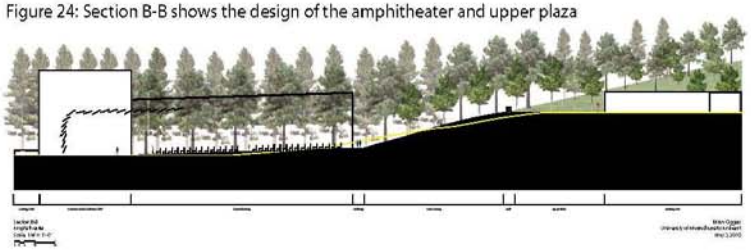


Figure 25: Section C-C shows the buffer treatment between vehicular and pedestrian circulation

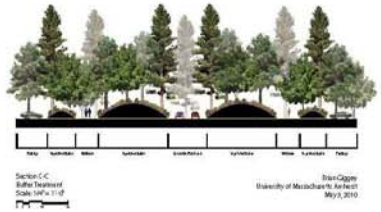
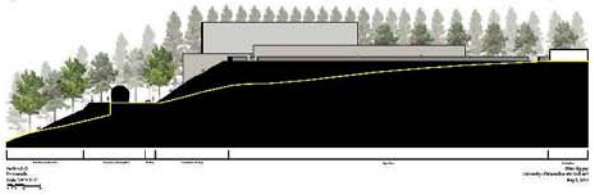


Figure 26: Section D-D shows the relationship of the promenade to the amphitheater and upper plaza



Figures 27-28: Perspective Renderings

Figure 27

The pedestrian experience along the parking lot at Mountain Park. Landform and vegetative buffers differentiate pedestrian from vehicular circulation as the buffers attenuate sound from entering the central portion of the site. Pedestrian circulation runs parallel to the woods and Mountain Park Road up to the amphitheater.

Figure 28

A bird's eye view of the amphitheater oriented north to south, aiming sound into the face of Little Mount Tom. The promenade around the existing rock offers access to the center of the site and acts as a gathering space as views over the site and South Hadley are particularly nice there.

Figures 29-30: Perspective Renderings

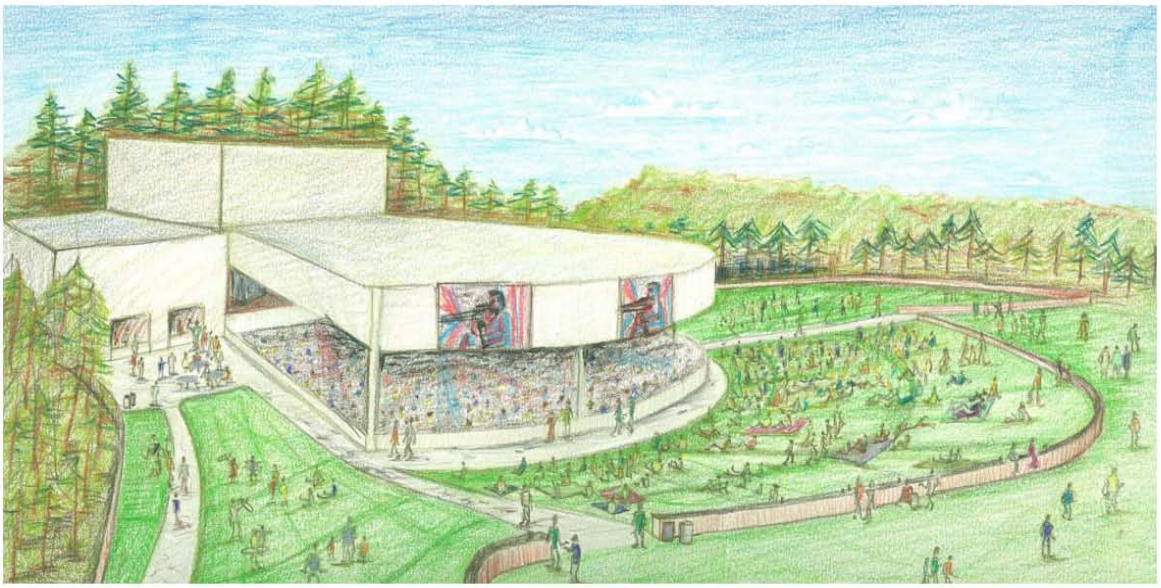


Figure 29

Looking into the amphitheater from the upper plaza. Reserved, covered seating lends its way to general admission lawn seating before reaching the upper plaza which provides views over the entire site. Video screens on the facade of the structure provide a closer look at the performance. Wing entrances provide ease of circulation while handicapped access on the far left connects the stage and upper plaza to the promenade and existing rock.

Figure 30

Looking over the amphitheater from Mount Tom Ski Road, the highest point on site. The upper plaza and extended lawn provide views into the Whiting Reservoir and South Hadley as vending and canopy covered seating attract concert goers to the top of the site.

5.3 – Conclusion

With thorough research on acoustics and site analysis conducted throughout the project, there is a strong understanding regarding the soundscape design opportunities and challenges of Mountain Park and its surrounding context. Extensive research was conducted on innovative techniques in soundscape planning, from the planning stages of the project to the design and modification of landscape media. Research, case studies, and personal observations helped identify techniques used in sound amplification in regards to structural design, construction materials and landscape media. Technical specifications of amphitheater design, reverberation times and attenuation of sound through landscape media, and then enhancement of sound through design and construction were all studied. The knowledge base integrated through the research process was then demonstrated in the conceptual master plan of Mountain Park.

With historic structures remaining on site, such as the rock and open-air structure, the design of Mountain Park tried to take advantage of those features as much as possible. The use of the existing open-air structure within the parking lot as a parking and vending permitting station as well as providing concessions and restrooms will serve to attract a lot of people before entering the main portion of the site. This open-air structure is a great place to take the time to educate the public about the landscape and soundscape they are experiencing. A display with writings and photographs of the historic amusement park and other features on site would go well in this area, as this exact location was where the rollercoaster and Midway were located. Another opportunity for education about Mountain Park's history comes at the promenade located around the existing rock above the shade grove. A plaque on the rock itself or signage scattered within the shade grove could help show the public how popular these spots were back in the early 20th century.

The best location for a display about the history of Mountain Park and the benefits of appropriate soundscape planning would be within the concourse of the amphitheater. Historic pictures and writings can be displayed showing what exactly Mountain Park looked like 100 years ago. The display can show how the park celebrated the end of the trolley line, and how the amusements park slowly succumbed to the culture of the automobile. Now Mountain Park's design is mainly affected by the need to accommodate the impact of the automobile. The mitigation of noise pollution from nearby Interstate 91 was done through proper location of the amphitheater and design of landscape media. An

aerial map showing surrounding context could show the very minimal affect on surrounding land uses, which is one of the challenges of good soundscape design. This map could also show the broader context, the actual plot of land that was Mountain Park and the expansive trail system and attractions that lay in close proximity to it.

Through thoughtful design and implementation of successful performance features, Mountain Park can be a site talked about within the music industry for years to come. Implementing features from some of the most highly visited and revered performance spaces all over the country, Mountain Park offers a little bit of everything for everyone. Mitigating offsite noise pollution, designing a cohesive performance space, capturing views of the surrounding context, offering multiple refuge areas, and strong connections throughout the entire site, Mountain Park could soon enter the conversation of must see venues.

With heavy buffering from the noise pollution from the highway and on site parking, Mountain Park will enjoy enhanced acoustics on site. These enhanced acoustics will allow patrons to hear the birds chirping, the wind blowing through the trees, children laughing and people enjoying the space. With enhanced acoustics within the site, as well as around the surrounding area by Whiting Reservoir and the expansive trail system that runs throughout the Mount Tom State Reservation, Mountain Park can once again offer a place of refuge for residents of Holyoke and Western Massachusetts as a whole. As it was once a reprieve from city life, Mountain Park will once again provide a place of solitude worth visiting time and time again. Whether sitting under the shade grove, watching a performance, or hiking along the surrounding trail systems, Mountain Park will provide a place for rest and relaxation, helping rejuvenate the mind and body.

With a strong overall design, Mountain Park reaches far beyond its location in Holyoke along the Connecticut and scenic Route 5. Providing educational opportunities and restorative benefits to its visitors, the state-of-the-art amphitheater will hold some of the biggest shows in Western Massachusetts, bringing in a large demographic of visitors and music fans alike. With linkages to the surrounding context, Mountain Park offers something for everyone. Residents of Western Massachusetts will see Mountain Park flourish as ‘New England’s Finest Amphitheater,’ as its prime location, design and history will attract fans both new and old for generations to come.

APPENDIX

Absorptive Materials

To maintain similar reverberation times when audience capacity varies, a seating material with a similar absorption coefficient needs to be selected. If sufficient absorption is needed, the proper selection would be upholstered seating. An unoccupied upholstered seat has an absorption coefficient of x = 0.8, while an occupied upholstered seat has an absorption coefficient of x = 0.88. Depending on venue design specifications, less absorption may be needed and in that case, wooden seats would be ideal. They have far less absorption with unoccupied wooden seats having an absorption coefficient of x = 0.22, while an occupied wooden seat has an absorption coefficient of x = 0.4.

Another aspect used in the control of reverberation time is overhead panels, known as ‘clouds.’ These panels make up the orchestra shell and are typically a coated plywood panel with an absorption coefficient of x = 0.17. These ‘clouds’ decrease the initial time delay gap, but still allow enough sound through the proscenium for a sufficiently long reverberation time (White and White, 1980). ‘Clouds’ are most successful when panels vary in size and orientation, helping diffuse the sound and create a better sound texture. The ‘clouds’ can be changed in a matter of minutes to match the specific performance and can also retract to the ceiling if need be.

The stage can be constructed of wood or steel, but should include a hollow airspace. The stage plot can vary in size and orientation depending on venue, so a combination of materials is suggested (White and White, 1980). Steel supports can create the frame while wooden planks can be used as the surface of the stage. The wooden planks should be covered with a carpet for absorption. Absorption coefficients of carpets usually stay in the range of x = 0.55. The floor of the venue should be rather reflective and cost-effective. These two requirements usually lend the designer to choose a concrete floor with a very low absorption coefficient of x = 0.015.

REFERENCES

Acoustics. "Acoustics.com: Acoustic Information for Concert Venues, Arenas and Stadiums " Web. 1/25/2010 <http://www.acoustics.com/concert_venue.asp>.

Ando, Y., and Noson, D. *Music and Concert Hall Acoustics*. London: Academic Press, 1997. Print.

Aylor, D. "Noise Reduction by Vegetation and Ground." *The Journal of the Acoustical Society of America* 51.1B (1972): 197-205. Print.

Baggott, T. *Tom Baggott Interview*. Interview with Tom Baggott of Invasion Group Management. June 2009.

Beranek, L. *Concert Halls and Opera Houses: Music, Acoustics, and Architecture*. 2nd ed. New York, NY: Springer, 2004. Print.

Bohme, G. "Acoustic Atmospheres: A Contribution to the Study of Ecological Aesthetics." *Soundscape: The Journal of Acoustic Ecology* 1.1 (2000): 14–18. Print.

Boston Symphony Orchestra. "The History of Tanglewood " 2009. Web. 2/8/2010 <http://www.bso.org/bso/mods/toc_01_gen_images.jsp?id=bcat13050002>.

Brown, A., and Muhar, A. "An Approach to the Acoustic Design of Outdoor Space." *Journal of Environmental Planning and Management* 47.6 (2004): 827-42. Print.

Caffrey, J., and Forbush, J. *History of Little Tom Mountain, Holyoke, Massachusetts*. Beverly, MA: The Trustees of Reservations, 2005. Print.

City and County of Denver. *Red Rocks Amphitheater Venue Guide*, 2008. Print.

Cook, I., and Van Haverbeke, F. and United States. Forest Service. *Trees and Shrubs for Noise Abatement*. Lincoln, Neb.: University of Nebraska, College of Agriculture, Agricultural Experiment Station, 1971. Print.

Crisler, B. "The Acoustics and Crowd Capacity of Natural Theaters in Palestine." *The Biblical Archaeologist* 39.4 (1976): 128-41. Print.

Davis, B. *Brian Davis Interview*. Interview with Brian Davis, designer of New England Dodge Music Center. February 2010.

Declercq, N., and Dekeyser, C. "Acoustic Diffraction Effects at the Hellenistic Amphitheater of Epidaurus: Seat Rows Responsible for the Marvelous Acoustics." *The Journal of the Acoustical Society of America* 121.4 (2007): 2011-22. Print.

Ducharme, J. *Mountain Park*. Charleston, SC: Arcadia Pub.; 2008. Print.

Ecotourism and Adventure Specialists. "Tikal National Park in Guatemala." *Ecotourism & Adventure Specialists.* Web. 2/24/2010 <http://www.tikalpark.com/>.

Escobar, F. *Fracisco Escobar Interview.* Interview with Francisco Escobar of Tikal Tours. January 2010.

Fang, C., and Ling, D. "Investigation of the Noise Reduction Provided by Tree Belts." *Landscape and Urban Planning* 63.4 (2003): 187-95. Print.

Harris, C. *Handbook of Noise Control*. New York: McGraw-Hill, 1979. Print.

Hartig, T., Mang, M., and Evans, G. "Restorative Effects of Natural Environment Experiences." *Environment and Behavior* 23.1 (1991): 3-26. Print.

Hedfors, P. "Site Soundscapes: Landscape Architecture in the Light of Sound; Sonotope Design Strategies." VDM, Verlag Dr. Müller, 2003. Print.

Holyoke Planning Department. *Holyoke Open Space Plan*. 2005. Print.

Hudson, R. "Making Music Work: An Alternative Route to Local Economic Regeneration?" *Place of music: culture and economy, Conference held at University College, London.* 1993. 13-14. Print.

Johnson, F., Beranek, L., et al. "Orchestra Enclosure for the Tanglewood Music Shed." *The Journal of the Acoustical Society of America* 31.11 (1959): 1587-8. Print.

Kaplan, R., Kaplan, S., and Ryan, R. *With People in Mind: Design and Management of Everyday Nature*. Washington, D.C.: Island Press, 1998. Print.

Kupferberg, Herbert. *Tanglewood*. New York: McGraw-Hill, 1976. Print.

Mount Tom Range Commission. *Mount Tom Range Study*. 1993. Print.

Porteous, J., and Mastin, J. "Soundscape." *Journal of Architectural and Planning Research* 2.3 (1985): 169-86. Print.

Red Rocks. "Visiting Red Rocks " Web. 2/11/2010 <http://www.redrocksonline.com/pages/visiting/hist_geo.html>.

Shepherd, J. *Music as Social Text*. Polity Press Cambridge, 1991. Print.

Smith, S. "Soundscape." *Area* 26.3 (1994): 232-40. Print.

Street, J. "Local Differences? Popular Music and the Local State." *Popular Music* 12.1 (1993): 43-55. Print.

Suher, E. *Eric Suher Interview*. Interview with Eric Suher of Iron Horse Entertainment Group. April 2009.

U.S. Census Bureau. “Holyoke Quick Facts from the US Census Bureau." Web. 2/4/2010 <http://quickfacts.census.gov/qfd/states/25/2530840.html>.

U.S. Department of Transportation. "Physical Techniques to Reduce Noise Impacts - Audible Landscape - FHWA "Web. 4/5/2010 <http://www.fhwa.dot.gov/environment/audible/al4.htm>.

Waugh, F. *Outdoor Theaters; the Design, Construction and use of Open-Air Auditoriums*. Boston: R. G. Badger, 1917. Print.

White, H., and White, D. *Physics and Music: The Science of Musical Sound*. Philadelphia: Saunders College Pub., 1980. Print.