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FINAL DELIVERABLE

Title	Webster City Outdoor Ampitheater
Completed By	Nick Lemkau, Ben Kruse, Patrick Stelmach
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UI Department	Civil and Environmental Engineering
Course Name	Senior Design - CEE:4850:0001
Instructor	Tim Mattes
Community Partners	City of Webster City

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UNIVERSITY OF IOWA
DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING
Project Design & Management
(CEE:4850:0111)

RFP# 05-Spring 2019

Outdoor Amphitheater

KLS Engineering

Nick Lemkau, Ben Kruse, Patrick Stelmach

Table of Contents

Section I Executive Summary

The City of Webster City Iowa hired KLS Engineering to design an Outdoor Theater in the center of the city. Three major Design Phases were developed by KLS Engineering and were analyzed to determine the most appropriate design to be implemented. The primary objective of this theater is to serve the community with a unique setting to view concerts and other outdoor events together. KLS Engineering was founded in 2019 by three engineers with experience in concrete and foundation design, wood design, and steel design. The Three Design Phases were developed allowing for future expansion of the project as funds become available.

Several constraints were considered during the design process of designing the Outdoor Theater. Cost was the major consideration because the city's budget is limited, but the client wished to optimize the design with the money they had available. Additionally, the client requested the use of eco-friendly building materials with wood construction in mind. Located in a city park, a wood designed amphitheater would fit the desired outdoor aesthetic. Another major constraint that was considered was the location of the stage with respect to the floodplain. A creek runs behind the proposed stage location that seasonally exhibits high water levels resulting in flooding due to snowmelt and rain. When placing a concrete stage and theater structure in the floodplain, we needed to consider how runoff would be effected and if the seasonal floods would have a detrimental impact on the structural integrity of the theater itself. The last constraint we considered in design was the preservation of the east side of the hill in the park. During winter, the east side of the hill is a very popular sledding hill for the children in the town. Our client made it clear that they wanted to keep a significant section of the hill undeveloped for the sledding to be able to continue.

To combat these constraints, we have developed several different designs strategies in the project, each serving a unique purpose. As far as cost, our client informed us that the budget for the Outdoor Theater is limited in the beginning, but they expect to have an increase in funds in the future. Therefore, we have presented the City of Webster City with one final design consisting of Three Design Phases that can be constructed at different times as funds become available. We will be designing the stage roof structure entirely out of wood in an effort to use eco-friendly material and to match the aesthetic of the wooded park. As far as flooding is considered, we analyzed several different flood levels and probabilities to determine the average and maximum depth of flood waters in the low points of the park. As a result, the stage will be constructed as a concrete slab and elevated approximately 1'-9" above ground level. The average flood depth normally doesn't reach this level, but it will provide for safe protection of the stage during any flood. Concrete is the material of choice for the stage base due to its resistance to major erosion from flood water. Finally, to preserve the sledding hill on the east side of the hill in the park, the stage seating will extend up the hill, but on the western side. This design feature will keep the sledding hill intact while still providing adequate seating for audience members.

Phase 1 of the design is the lower budget option. In this design, we feature a 80 foot by 50 foot concrete stage with a back wall and side walls constructed with stamped and stained concrete for aesthetics. The stage will sit above ground level with appropriate ADA compliant ramps and stairs. Extending up the existing hillside will be 5 integrated levels constructed of grass stepped seating lined in concrete, each 10 feet wide. This design allows for the audience to bring lawn chairs and sit on the grass, or sit along the concrete step lining. With this design, the theater will be able to seat 2,000 people comfortably. Phase 2 is a higher level of design that can be completed when the funds are adequate. This upgraded design includes a slanted, wood constructed roof structure that will be added on top of the existing stage structure. The roof will provide for stage covering as well as assist in projecting the sound outward to the audience. Finally, Phase 3 of the design will feature lighting fixtures placed around the seating area. This addition will provide accomodation for night time shows and performances as well as deter potential vandals from damaging the stage and surrounding areas.

To assist in the selection of which Phase design to pursue, we have prepared a recommendation for our client as to how to approach the construction of the Outdoor Theater. Based on final cost estimation and features of each design level, we have put together a decision matrix that outlines the most important features, their cost, and their contribution to the intended objectives of the project. This decision matrix is shown in Appendix L, Table 4. We recommend the client begins with Phase 1 of the design. This Phase will provide the city with all the basic features that the client has requested in their theater, while also remaining within a reasonable budget. Additionally, as funds become available, Webster City can easily expand upon the theater to pursue Phase 2 and Phase 3.

<u>Section II Organization Qualifications and Experience</u>

1. **Name of Organization** KLS Engineering
2. **Location and Contact Information**
    a. Location: 3100 Seamans Center, Iowa City, Iowa 52242
    b. Contact Information:
        i. Name: Nick Lemkau
        ii. Phone: (303) 704-0466
        iii. E-mail: nicholas-lemkau@uiowa.edu

3. **Design Team Description**

We are a team of students enrolled in the capstone design class at the University of Iowa who worked with The City of Webster City in the completion of the Outdoor Theater design. Our team consists of Nick Lemkau, Project manager, as well as Patrick Stelmach, structural engineer, and Ben Kruse, civil engineer. Nick's roles included being the primary contact with client, organizing the group, providing structure to our meetings and work hours throughout the week, and verifying designs. Patrick's primary roles were formatting and organizing all written documents, keeping track of all meeting minutes, and assisting with structural design. Ben's primary roles included proficiency in all computer software to be used throughout the project, assisting with some structural design, and completing the required sitework for the construction.

Section III Design Services

1. Scope

The overall objective of this project was to design an outdoor amphitheater with the primary function of serving musical venues such as musicians and orchestras. Additionally, it needed to be versatile enough to accomodate things such as movie showings and other miscellaneous events the community may be interested in. One of the largest constraints in this project was the cost, so we decided to create an expandable design that the client will be able to add on to when they have enough funding to do so.

The first major task that we completed was the locating of the stage on the site. This was perhaps the most important decision, as the stage was going to have to be built in the floodplain of a nearby creek so we needed to design with that in mind, we wanted to utilize the hill to the best of our ability for maximum acoustical effect and optimal seating arrangements, and finally it was requested by our client that we keep the stage relatively close to an existing gazebo and avoid disturbing the sledding hill which is popular during the winter. After all these constraints were taken into account and we had our location, we began working on the stage design and sitework simultaneously. We started the stage design with the platform and stairs, then designed the roof, and finished by design the rear wall and support columns in the front. For the sitework, we created new elevation contours for the seating plan and then tied those into the existing contours to create a smooth transition into the seats. We then created a sidewalk and tied that into the existing sidewalk so people will have access to the stage area from the bike path.

2. Work Plan

Figure 1. shows a Gantt chart of the work completed by the group and the duration of each event. As can be seen, a good amount of research and planning was completed before any actual design took place. This was important, as it allowed for our group to try and decide the best possible

way to optimize the stage and site design before jumping into the calculation and risk making careless mistakes.

Task Name	Duration	Start	Finish
⊟ Research	15d	02/11/19	03/01/19
seating design	5d	02/11/19	02/15/19
stage dimensions	5d	02/18/19	02/22/19
site layout	5d	02/18/19	02/22/19
obtained relevant cod	5d	02/25/19	03/01/19
⊟ Sitework	35d	02/11/19	03/29/19
created model of site	5d	02/11/19	02/15/19
placed stage and seat	15d	02/25/19	03/15/19
contour editing	11d	03/15/19	03/29/19
runoff calculations	5d	03/25/19	03/29/19
⊟ Design calculations	20d	03/11/19	04/05/19
gravity loads	5d	03/11/19	03/15/19
lateral loads	16d	03/11/19	04/01/19
structural member sizi	10d	03/25/19	04/05/19
foundations	5d	04/01/19	04/05/19
stage design	5d	04/01/19	04/05/19
⊟ BIM model	20d	03/11/19	04/05/19
stage model	16d	03/11/19	04/01/19
details	10d	03/25/19	04/05/19

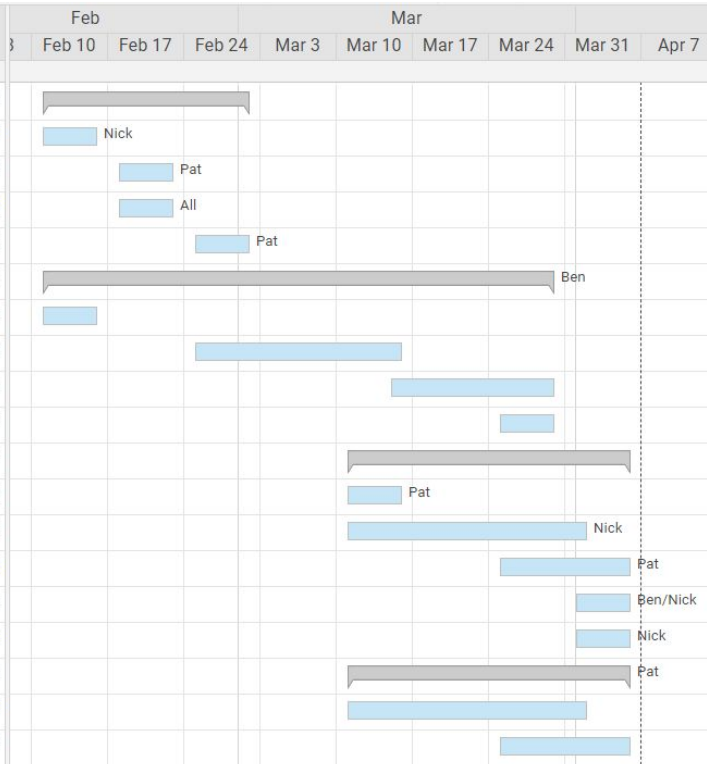


Figure 1: Gantt chart of the tasks completed

<u>Section IV Constraints, Challenges, and Impacts</u>

1. Constraints

The biggest constraint for this project was the physical location of the stage on the site. It was requested that we disturb the hill in the least amount possible, as it is a popular sledding area for kids in the winter months. Along with this, we were told that it would be nice if we could keep the stage somewhat close to a nearby gazebo so people can quickly access it to use the restrooms or have access to the vendors. The fact that this stage is in a flood plain also was taken into consideration, as we wanted to create a design that will last even though it may be partially submerged in water at times. Finally, we tried to utilize the hill as best as we could for optimal acoustical quality. All of these factors were taken into consideration when we made our final design.

Another constraining consideration for this project was ADA compliance. It was requested that disabled people would be able to have as much access to seating and stage areas as people without disabilities, so we had to keep ramp slopes, stairs, and railings in mind at all times when creating our design.

Funding was an additional major constraint that we needed to consider for this design project. Our client informed us on their current funding for the project and how they expect to receive more down the road, so it would be best to construct a design that could be expanded upon over time.

Lastly, we needed to consider the duration of construction. There is an elementary school in the lot adjacent to our site, so ideally the project would have to be completed during the summer months so as to not disturb the children in class.

2. Challenges

The first large issue we faced was designing with floodwaters in mind. There is a large flat area near the bottom of the hill in our lot, and during flood season water has a tendency to pool there, which could potentially be dangerous to a structure in that vicinity. While we initially thought that this would be running water posing a threat to our stage, we came to find out that the biggest hazard in the area is actually standing water leftover after a flooding event, so this was factored in when we created our design. To mitigate this,we decided to create the stage nearly two feet above the ground that would be accessed by stairs and a ramp rather than just laying the slab into the existing ground. This is ideal because not only does it prevent the stage from being damaged, but it also keeps the columns and rear wall out of the water so the aesthetics they offer won't be hindered.

Another challenge faced was the fact that the stage design had to be expandable. Our client mentioned how they expect to get more funding for the project at a later time but would like to have the stage sooner rather than later, so we created two alternatives for them to choose from. The reason this was a challenge is because part of the proposed expansion would involve either destroying part of the stage or carefully designing the stage with the knowledge that it will be altered in the future. Our solution to this was to design the foundations under the stage with the knowledge that there will be a structure there at some future point in time and make things as easy as possible for contractors to complete the necessary work for the expansion.

3. Societal Impacts within Community

Some long term societal impacts include bringing the community together through attractive events. Having a gathering area such as this amphitheater in the heart of community would unite residents and provide fun and entertainment for all ages. The amphitheater would also be aesthetically pleasing for nearby residents; instead of the open field that exists there now, a pleasant structure and nice landscaping would be present.

The largest negative societal impact will take place during the construction phase of the project. The site is in close proximity to an elementary school, and heavy construction equipment will make noise that could potentially disrupt or frighten the young children nearby. To combat this, we could schedule most of the construction during the summer months when the kids wouldn't be in school.

Section V Alternative Solutions Considered

We ended up considering Three Design Phases that in the end were the same design, just at different stages of completion. Phase 1 features a stage without the roof, but still included the side and rear walls. The initial idea for this was to have just the stage and seating, but after we began our design we realized that if we wanted to have a wall on the stage at all, it would need to be included in the initial design. This is due to the fact that the contractor would have to destroy part of the stage, dig under it to lay the foundation for the wall, and then repair the stage in order to complete the expansion. We found it to be cheaper to just build with the wall there initially to avoid destruction. That leads to the first con of this design: the aesthetic. While the wall will be stamped and stained to make it visually appealing, some people may find it odd or out of place to have just the wall on the stage with no roof. However, we believe that we can tie this into the design to make it look like as natural a part of the structure as possible. This design also features seating etched into the hillside along with a flat area in front of the stage that can be used as viewing area by disabled audience members. The seating will be accessible by ramps lining each side, but can also be navigated by simply walking on the platforms of each seat. The seats will be lined with two feet of concrete around the edges to help maintain the shape as well as give a sharp look to the area. The second con of this design is the decreased acoustical amplification brought on by the lack of the roof. The roof is a critical part in getting the sound to carry to the audience instead of being lost overhead or to the surrounding areas, and not having this feature will slightly detract from the overall functionality of the stage. However, since the wall is still there and the seating slope was designed to optimize sound amplification, we do not believe this to be too large of a problem.

Phase 2 is an extension of the first level, however this design features a wooden roof covering most of the stage. The roof is supported in the front by wooden columns and supported in the back by short wooden columns attaching it to the bearing wall. This design features the same elevated stage and seating etched into the hillside.

Finally, Phase 3 is the final design stage of completion that includes the addition of lighting fixtures along the outside of the seats. These lights will provide opportunity for nighttime performances and hopefully help to prevent any crimes or vandalism from occuring in the area.

Section VI Final Design Details

Our final design is best represented by Phase 3 of the design. As stated above, this alternative includes the stage, roof, rear and side walls, seating etched into the hillside, and lamps alongside the seats.

To start, the seating was designed with ADA compliance and optimal acoustical affect as the top priorities. Before the start of any seating, we created a large, flat, paved area directly in front of the stage with the intent of accommodating disabled people and their families. After this, we decided on five total seating rows spaced at 10 feet each. These will be lined around the edges with two feet of concrete, and the step size will be 1'-6". The proposed elevations of each seating area can be seen in drawing S7. This design was decided on based off of both aesthetics and functionality as well as ease of tying into the existing contours of the hill. The 10 foot rows allow for plenty of walk way so people will not be stepping on top of eachother was they navigate to their seats, and they will have plenty of room to bring their own lawn chairs or towels or anything else they may want to sit on to view a show. The 1'-6" step size serves as a seat people can use for viewing, and it also helps to create an optimal slope in the hill for sound to travel to the audience. Lastly, the two feet of concrete lining each row serves to prevent erosion and hold the hillside together as well as look nice. We spent time researching existing outdoor theaters with similar seating designs as ours and concluded that the 1:5 concrete to grass ratio on each seat held the ideal aesthetic look.

Next, the roof design was created after spending some time researching ideal spacing of members to try and cut down on material costs. The roof dimensions are 40' X 60', which does not cover the entirety of the stage, but this is by design as we feel as though it adds a bit of an architectural edge to the finished product. For the structural members, we ended up settling with an entirely wooden design featuring purling spaced at 2'-6" O.C. (Appendix D) framing into beams spaced at 10' O.C. (Appendix D) that are supported in the rear by columns and in the front by one large girder spanning the entire front length of the stage. We found it best to have larger spacings and spans to try to cut down on material costs as best as we could. Due to this, we have some members that are quite large. Each column (front and back) is a 14" X 14" timber section (Appendix E). The front columns function as a part of the lateral (wind) force resisting system, and are driven deep into the ground. This option was selected because creating moment connections is very difficult when designing wooden structures, and we did not want to include any sort of lateral bracing elements because we felt that this would take away from some of the aesthetics of the stage. The rear and side concrete walls are each also 14” thick, which is due to the fact that the columns resting on them are that size and this was necessary to tie them together. The rear wall also serves to help resist lateral forces, and it does this by having a large, wide footing that resists overturning. The side walls actually do not resist any forces, however they are there to help project sound. We found it best to make all walls the same thickness to keep consistencies throughout the design.

The stage itself is elevated a minimum of 1’-9” off the ground to prevent damage due to flooding. After researching flood data and talking with our client, we found out that the area is mainly affected by standing water after a flood as opposed running water, so our flood mitigation technique was to simply elevate the stage above the point in which the water would normally rise. This created the need for stairs leading up to the stage, which we provided on either side of the stage. To keep up with our efforts to make this project ADA compliant, we also provided an ADA compliant ramp along the left side of the stage. This ramp ties directly into the sidewalk that will tie the stage to the existing bike trail, so disabled people will have easy access should they want to get on the stage.

The slab that makes up the stage is going to be 4” thick, which is a typical slab on grade thickness. To give this slab more longevity, we will be including 4x4-W2.9x2.9 Rolled Welded Wire Fabric to prevent temperature and shrinkage cracking (Appendix F). Beneath the stage is the foundation, which is designed to support the final phase of design. This means that, should the client choose to construct Phase 1 first, the foundation that supports the columns of the roof will not be providing any structural support to the design. We have specified that this area will be excavated during initial construction and then backfilled with gravel enclosed in a steel casing. This will provide ease of construction for future renovations as the demolition footprint will be smaller and the groundworks for the concrete work will already be laid.

Section VII Engineer’s Cost Estimate

Table 1: Cost estimate for the completion phase 1

Item	Units	Quantity	Unit Price ($)	Total ($)
Steel Reinforcement	Ton	20.3	2,125	43,137.50
Concrete	Cubic Yard	378	450	170,100.00
Site Work	Cubic Yard	1126.68	21.5	24,223.62
Construction Sub-Total	-	-	-	**237,461.12**
10% Contingencies	-	-	-	23,746.11
5% Engineering/Admin.	-	-	-	11,873.06
TOTAL COST				**273,080.00**

Table 2: Cost estimate for completion phase 2

Item	Units	Quantity	Unit Price ($)	Total ($)
Steel Reinforcement	Ton	20.3	2,125.00	43,137.50
Concrete	Cubic Yard	378	450.00	170,100.00
Structural Framing	M.B.F	1.081	1,750.00	15,950.00
Demolition	Square Feet	40	20.00	800.00
Site Work	Cubic Yard	1126.68	21.50	24,223.62
Construction Sub-Total	-	-	-	**254,211.10**
10% Contingencies	-	-	-	25,421.11
5% Engineering/Admin.	-	-	-	12,710.56
TOTAL COST				**292,343.00**

Table 3: Cost estimate for completion phase 3

Item	Units	Quantity	Unit Price ($)	Total ($)
Steel Reinforcement	Ton	20.3	2,125.00	43,137.50
Concrete (Theater)	Cubic Yard	378	450.00	170,100.00
Structural Framing	M.B.F	1.081	1,750.00	15,950.00
Demolition	Square Feet	40	20.00	800.00
Lighting	Units	10	1,025.00	10,250.00
Site Work	Cubic Yard	1,126.68	21.50	24,223.62
Sidewalk (Concrete & Site Work)	Cubic Yard	530	17.90	9,487.00
Construction Sub-Total	-	-	-	**273,948.10**
10% Contingencies	-	-	-	27,394.81
5% Engineering/Admin.	-	-	-	13,697.41
TOTAL COST				**315,040.00**

Tables 1-3 show our estimated costs for each stage of completion. As can be seen, as the stages of completion progress so does the cost of construction. The biggest addition to the initial design is the cost of the roof (covered in structural framing), but the lighting will also be significant should the client choose to install those at some point. All values in this table were calculated using RSMeans 2018.

APPENDIX L

American Concrete Institute (2011). *Building Code Requirements for Structural Concrete (ACI 318-11).* Farmington Hills, MI.

American Society of Civil Engineers (2017). *Minimum Design Load and Associated Criteria for Buildings and Other Structures*. Reston, VA.

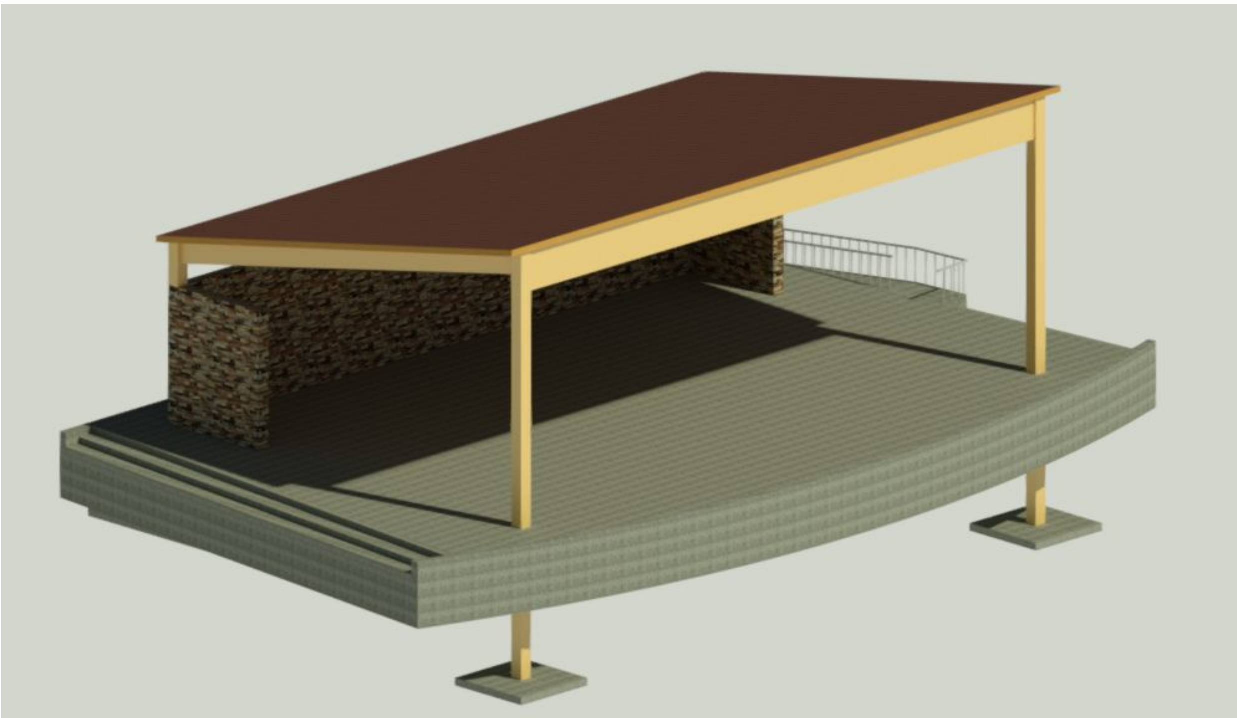
American Wood Council (2014). *National Design Specification for Wood Construction.* Leesburg, VA.

City of Webster City (1996). *City of Webster City Code of Ordinances*. Webster City, IA.

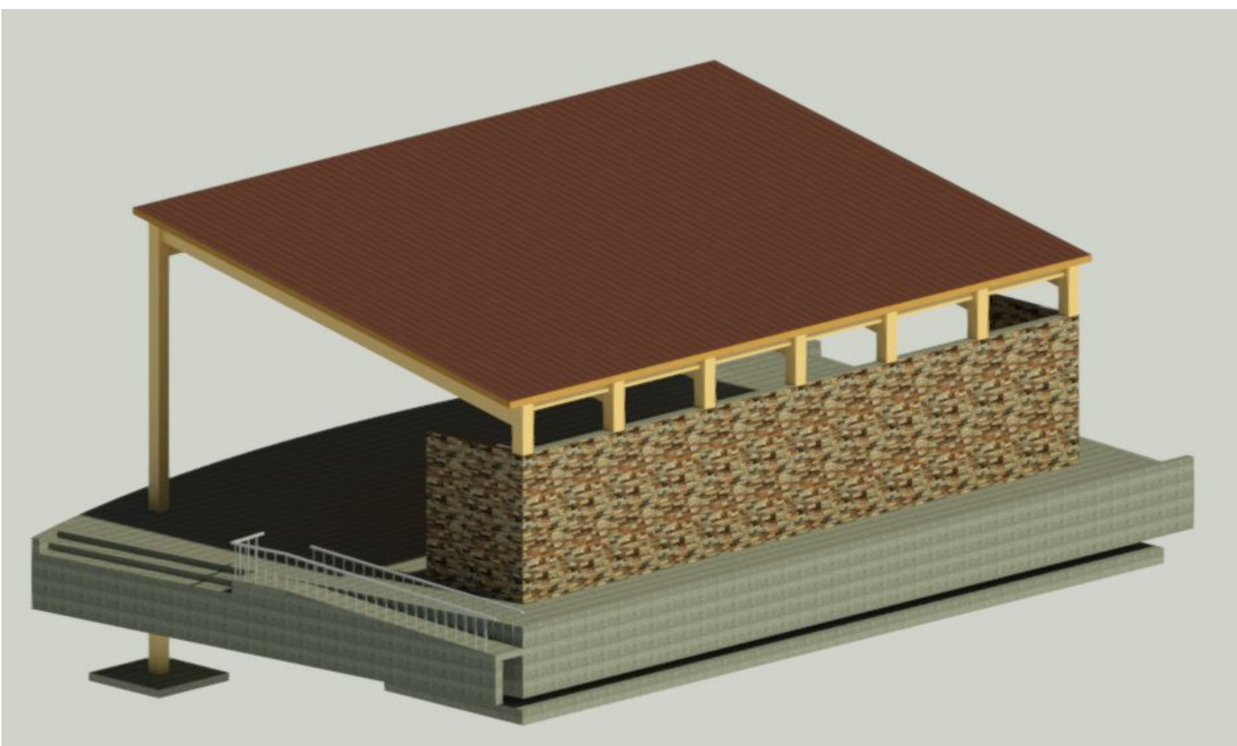
International Code Council (2015). *International Building Code.* United States.

Iowa State University (2019). *Iowa Statewide Urban Design and Specifications*. Ames, IA.

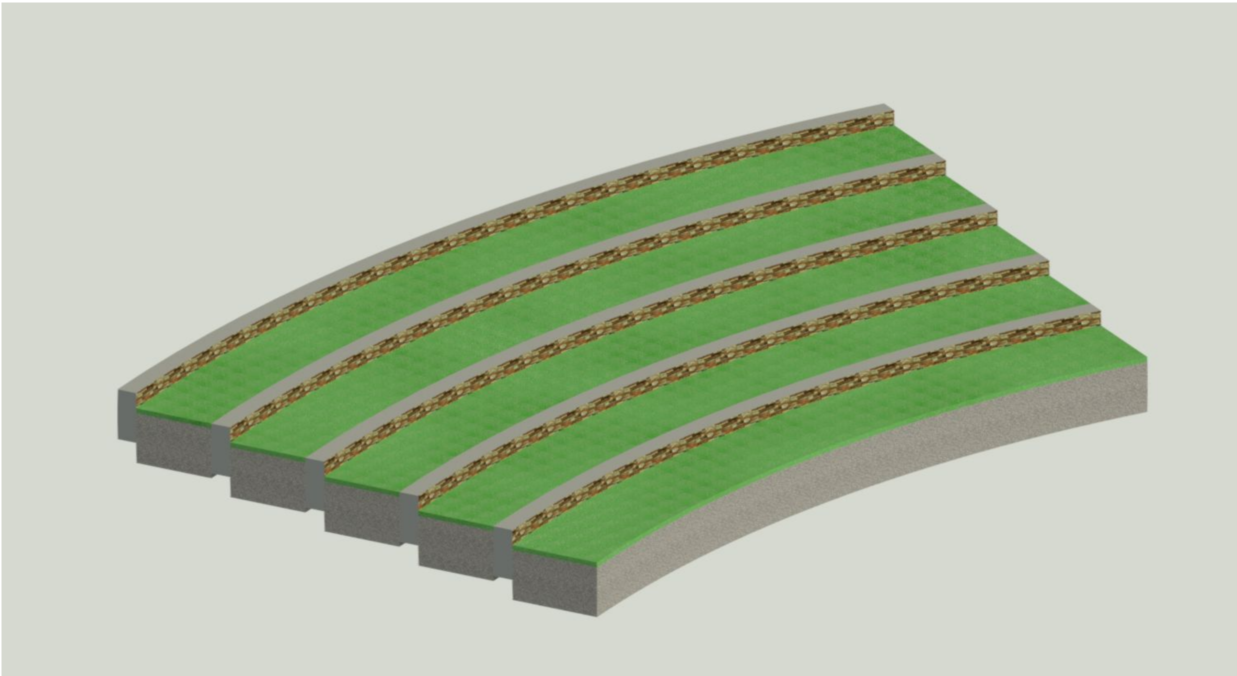
Design Renderings and Models



Rendering 1: Northeast aerial view of final stage completion



Rendering 2: Southwest aerial view of final stage completion



Rendering 3: Southeast view of integrated hillside seating

Table 4: Design Decision Matrix

Decision Matrix												
		Quantities				Rank				Score		
Criteria	Weights	Phase 1	Phase 2	Phase 3	Total	Phase 1	Phase 2	Phase 3		Phase 1	Phase 2	Phase 3
Upfront Cost	9	3	2	1	6	0.50	0.33	0.17		4.50	3.00	1.50
Aesthethics	10	1	3	3	7	0.14	0.43	0.43		1.43	4.29	4.29
Construction Time	5	3	2	1	6	0.50	0.33	0.17		2.50	1.67	0.83
Venue Accommodations	3	1	2	3	6	0.17	0.33	0.50		0.50	1.00	1.50
									FINAL SCORE	***8.93***	***9.95***	***8.12***

Key:
1-Worst: Least Aesthetic, Most Construction Time, Most Expensive
2-Middle Ground
3-Best: Most Aesthetic, Least Construction Time, Least Expensive
Highest Score: Best Option