5-2022

Co-habitation and Migration: Urban Design for Bird Migratory Pathways

Steve C. Kurtz
stevek@g.clemson.edu

Co-habitation and migration:
Urban design for bird migratory pathways

MASTER OF LANDSCAPE ARCHITECTURE

TERMINAL PROJECT

SPRING 2022

Steve Kurtz
CLEMSON UNIVERSITY | LANDSCAPE ARCHITECTURE PROGRAM

TABLE OF CONTENTS

01 Introduction

Background

Introduction

Migratory bird flyways exist through various corridors around the world (Tietze 2018). These system have been divided by urban areas (Hilty, Keeley, Lidicker Jr., and Merenlender 2019). There exists an opportunity to restore original migratory bird routes and endangered species through the examination of green roof location and design in urban settings (Brenneisen 2004).Urban areas have fragmented many of the natural migratory corridors that existed before urbanization (Hilty, Keeley, Lidicker Jr., and Merenlender 2019). The direct impacts of this fragmentation have led to various consequences. Fragmentation can be a natural process, although natural and human induced fragmentation vary significantly. Human induced fragmentation is far more accelerated then naturally occurring fragmentation. This acceleration has changed the structure and habitat of countless bird species (Hilty, Keeley, Lidicker Jr., and Merenlender 2019). Green roof designs have shown positive consequences when implemented throughout urban areas (ASLA Green Roof, 2021). Few studies have been conducted showing the impacts that green roofs can have on migratory species. The collection of these results shows promising data on the biodiversity that can be introduced within urban areas (Eakin 2015).

Urban landscapes are intricate systems interacting throughout the globe. Over the past decades, urban development has widely sprawled and fragmented flyway systems and corridors. This has led to many changes in species composition and has even caused the extinction of some animals (Marzluff 1997). Recent studies have indicated that there exists a protective or restorative design to create stepping-stone connectivity in urban areas. This study looks to understanding potential benefits in urban biodiversity, animal species protection, and urban benefits of green roof designs.

Building the Problem

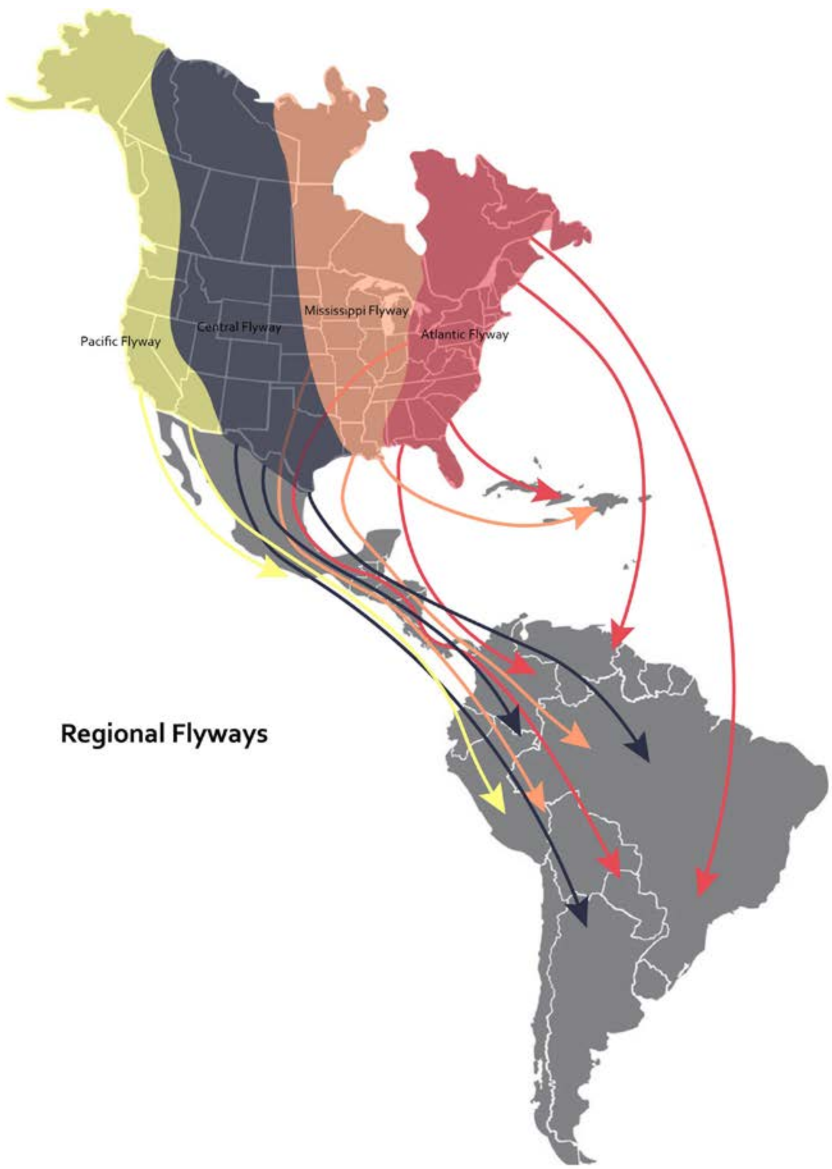


Figure 1

Existing Conditions

There are four primary flyways in the United States. They include the Pacific Flyway, Central Flyway, Mississippi Flyway, and the Atlantic Flyway (U.S. Fish and Wildlife Service 2021) (Figure 1). Flyways are bird "highways" for migration. Along these flyways birds look to find shelter for rest, food, and some nesting areas. There are over 1000 bird species that fly along the flyways each year (U.S. Fish and Wildlife Service 2021).

Figure 2

Flyway Key Issues

The Atlantic Flyway (Figure 2) is the most densely populated flyway among North America (Hilty, Lidicker, and Merenlender 2019). 1/3 of the US population lives within the Atlantic Flyway. There are over 500 bird species that fly along the Atlantic flyway each year (U.S. Fish and Wildlife Service 2021). Given the urbanization of the area much of this flyway has been fragmented.

A corridor is any space that facilitates connectivity over time among habitat patches (Hilty, Lidicker, and Merenlender 2019). Specific corridors are used by migratory birds. These corridors are known as Seasonal Migration Corridors. Fragmentation is a cause of breaking these corridors (Figure 3). There are two variations of this. They are natural and human-induced fragmentation. There are three primary differences between the two. The first is the speed and pattern of change. Typically, human induced fragmentation is much faster. Examples include the rapid building of cities within the Atlantic flyway. The second would be the scale of the change. Naturally, many changes are localized. Human induced fragmentation happens at a much larger scale, as one can imagine the footprint of many structures within a city. The final is the ability of the resulting fragments to recover from the changes. This is usually the measure of an ecosystem's resiliency (Hilty, Lidicker, and Merenlender 2019). As fragmentation continues, there are notable negative effects on migratory patterns. Migration patterns have become longer, and more strenuous for some species of birds. As green roof implementation increase, viable environments are being created within urban areas for these migratory birds. Birds making this long journey use these green roofs as a point to rest and feed. Data can be seen through European green roofs, as they provide environments for migratory birds. This begins to build the argument further for green roof implementation, outside of the benefits of runoff and heat island reduction.

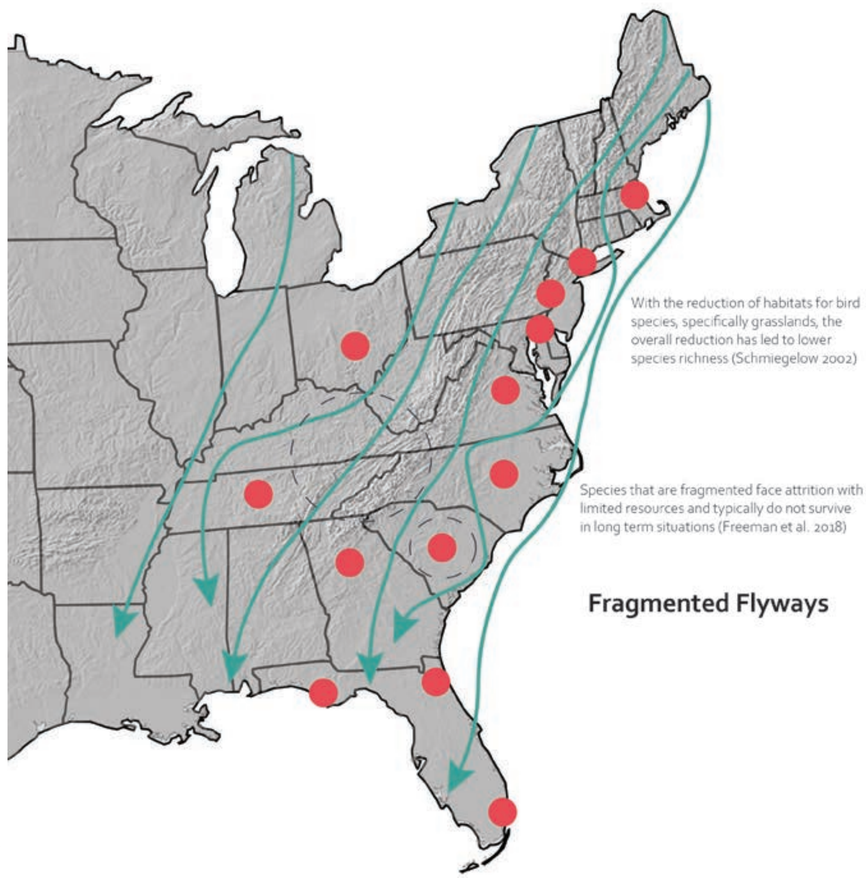


Figure 3

Fragmentation has led to various consequences that have directly impacted bird species. The literature suggests the following changes among bird species. Generally, with the reduction of habitat for bird species, specifically grasslands, the overall reduction has led to lower species richness (Schmiegelow 2002). This suggests the cities that have been created on these lands that were once grasslands has led to reduction of species diversity. This has been observed within urban areas and highlights the homogenized bird species found in urban areas. Research continues to show that these bird species that have been fragmented are species specific. This applies to the categories of birds being avoiders, utilizers, and dwellers. Studies have documented that those species of lower densities are more likely to go extinct. Species that are fragmented face attrition with limited resources and typically do not survive in long term situations (Freeman et al. 2018). The stress placed on these bird species is not sustainable. Habitat for these birds is being destroyed continuously as we create more cities. The effects do not necessary always need to be in a negative light. The opportunity for habitat creation, is equal to urban development. The technology exists to amend the fragmentation. Urbanization trends shows an increase in urbanization throughout the United States (UN Data 2021). (Figure 4)

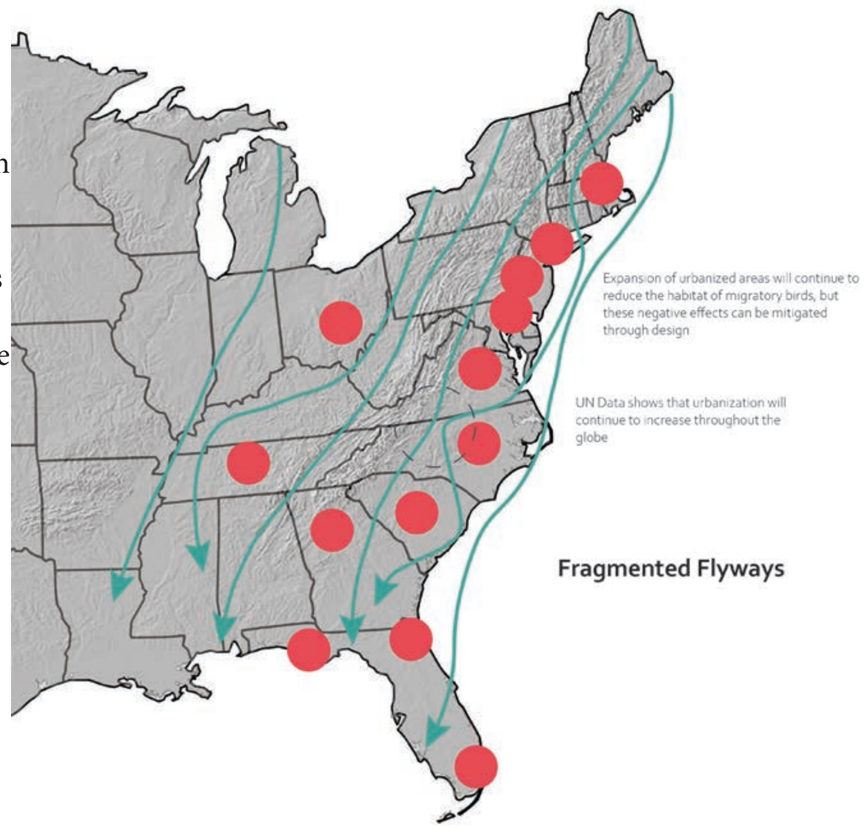


Figure 4

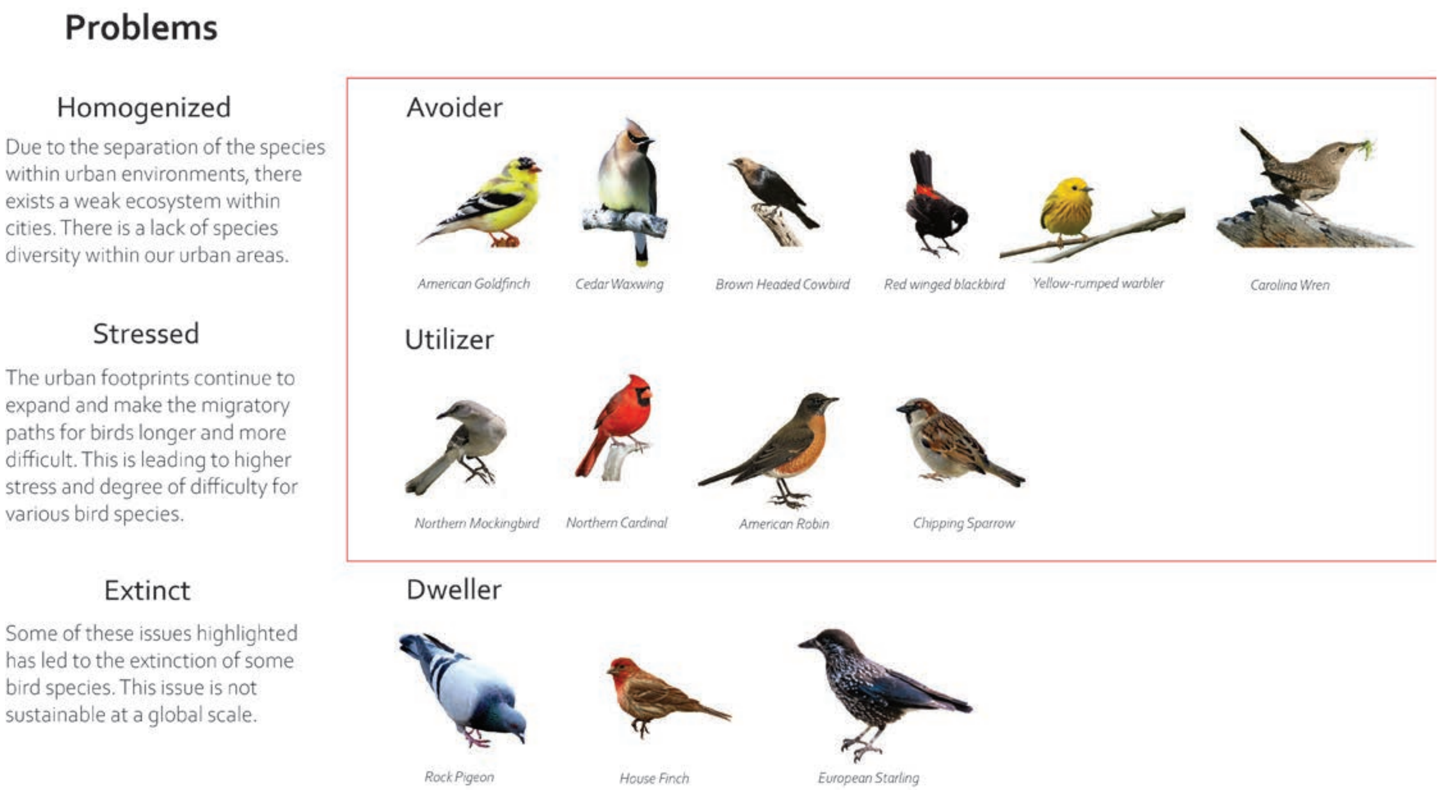


Figure 5

Some of the key issues are highlighted above in Figure 5. These issues are directly correlated to the seperation of bird species. Figure 5 also highlights some common bird species in relation to their catagories. (Hilty, Lidicker, and Merenlender 2019)

Literature Review

Green roof implementation has become highly incentivized through government mandates and has been seen by the public as a wonderful effort to create a rich environment in urban areas. These assumptions have largely proven benefits. As green roofs continue to be implemented other benefits have been highlighted. They are beginning to have a positive impact with bird migration patterns along flyways. For this study, highlighting benefits of green roofs builds the argument for further implementation and innovation of green roofs, and moving towards new research showing potential in stepstone migratory connectivity in green roofs within urban areas.

The leading incentive for urban green roofs is the benefits against heat island effect. Heat island effect is a measured issue that has been occurring in large cities throughout the world. This phenomenon has caused temperatures throughout cities to spike and increase levels of pollution in our atmosphere. This heat traps various gases and volatile organic compounds (VOCs) that then react with sunlight to create what is known as smog (Figure 1). Green roofs have proven to help increase albedo and reduce surface temperatures (Peng and Jim 2013). Research indicates that 50-60% of rooftops within densely populated areas could decrease summer temperatures by as much as 10 degrees Fahrenheit (Luckett 2009). This has been the leading incentive for green roof implementation. Typically, in design, this is the argument presented for green roof designs and budgeting within urban areas.

Another incentive to green roofs is increase in air quality. This claim is true, but not in the way many may assume. Research shows that oxygen is produced by sunlight-driven photosynthesis is water, not carbon dioxide (Luckett 2009). Typically, due to weight concerns, green roofs look to use minimal amounts of water and therefor the production of oxygen is limited. This loosely disproves another leading argument for green roof implantation.

The final popular use for green roofs is storm water management. Green roofs have been proven to be very affective in storm water management practices. Research conducted at Southern Illinois University, Edwardsville concluded that a green roof with 4 inches of growth media can retain over 50% of annual rainfall in relation to surface area and conventional roofing methods. Live measurements can be found on the ASLA website. The ASLA has created a green roof with live monitoring to see real time results and benefits of green roof design. This research enforces the use of green roof in urban areas and is a pillar of urban sustainable design (Figure 2).

In recent studies, a new benefit has been noticed. As green roof implementation increases, more birds have been migrating through cities. Historically, bird species have seen major shifts as urbanization rapidly occurred throughout the migratory flyways. A new field has risen in recent years focusing on ecological resilience. This is defined as the capacity of a system to withstand changes to the processes that control its structures (Holling and Gunderson 2002). Disturbing ecosystems can reduce resilience and cause weakening in ecosystem's capacity to sustain basic necessities to the wildlife (Hilty, Lidicker, and Merenlender 2019). Urbanization has led countless flyways to be fragmented for various migratory species. This pressure on the ecosystem has led to various negative effects on bird species.

Precedent Studies

New York Study

A study conducted by the department of biological sciences in Fordham University, Bronx, NY examined the potential of green roofs providing new habitat for wildlife in New York City. The study surveyed birds and arthropods on green roofs in Manhattan, Brooklyn, and downtown Bronx. The study was conducted during the spring migration period and the breeding season. The birds were monitored using automated acoustic recorders (Model SM2). The monitors recor the sounds of birds that are nearby, and that audio is then downloaded and analyzed. The software can separate the sounds and isolate bird species that were on the roofs.
The study concluded that green roofs appear to be an effective tool for wildlife conservation. The green roof system holds various arthropods that are prey for the birds and provide a valuable food source, that are more sparce across urban areas. The study also shows that there were more urban utilizers than urban avoiders on the green roofs. This conclusion leads to further studies that can be conducted in order to investigate potential factors in providing a viable environment for urban avoiders. The study found that the American goldfinches and cedar waxwings were some of the more common urban avoiders that were spotted in their testing. (Partridge 2018)
The study supports the research in investigated green roof designs for urban bird migration. The study shows promise to incorporate bird species based on plant design within the green roof. Further research can be conducted to increase species diversity through green roof design.

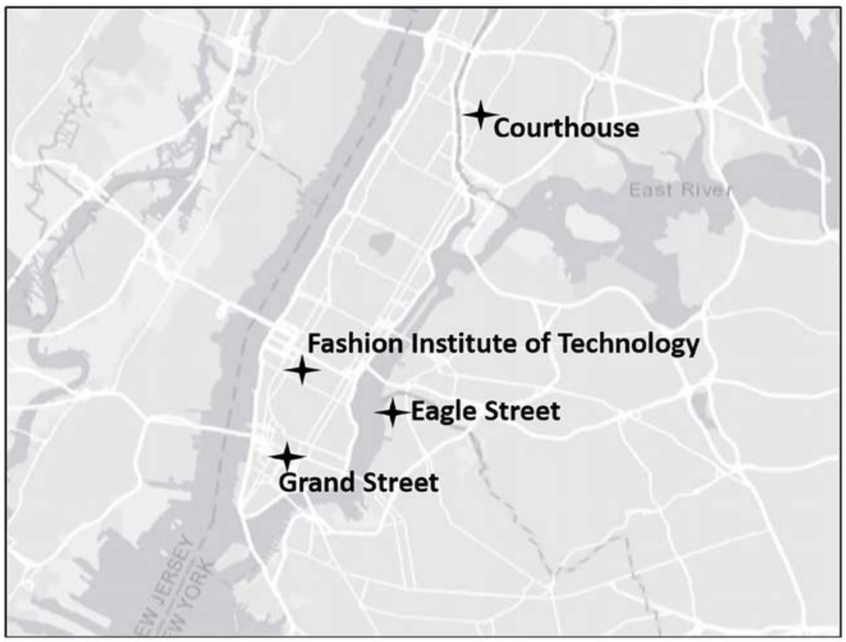


Fig 1. Location of four paired sites (green roofs versus nearby comparable conventional roofs) sampled during spring bird migration (late April and May 2011 and 2012) and the bird breeding season (June to mid July 2011 and 2012) in New York City.

https://doi.org/10.1371/journal.pone.0202298.g001

Figure 6

Midwest Study

Carly Eakin, part of the department of fisheries and wildlife at Michigan State University conducted a study in 2015 that observed 12 green roofs in the midwestern United States. The study looked to find avian responses to green roofs found in urban areas in the Midwestern United States. The study was focused on the Mississippi flyway and the study began a visit to over 108 green roofs, and the largest were then selected for the study. The data was collected over 2 seasons and recorded over 2,973 species of birds.

The study concluded that there exists an opportunity for green roofs to provide a rich environment for bird species. A few bird species were found to have occupied the green roofs more than the surrounding areas of landscape. (Figure 7) This suggest that there exists an opportunity for green roofs to facilitate a rich environment for bird species. The study also explains that there doesn't seem to be a correlation between the size of a green roof and bird occupancy, although when cross referencing this claim with the habitat study of birds, it is biologically important for birds to have an appropriately sized area for nesting and forage (Evans 2008). The study also shows that some unexpected species that were recorded in the study may have been in the green roof environment due to fewer disturbances in the surrounding area (Eakin 2015).

The study supports the investigation of green roof designs, reflecting species specific environment, further backing the research in tailoring a green roof design for a specific species of bird. A critical issue that needs to be resolved within urban areas and the larger migratory system as a whole.

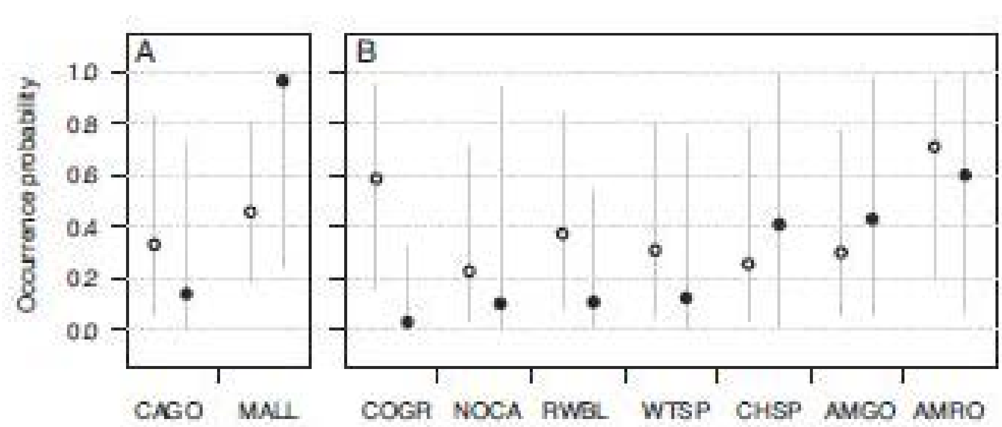


Figure 7

Switzerland Study

A study was conducted by Nathalie Baumann from the University of Applied Sciences Wadenswil, Switzerland, to investigate the habitat potential of flat roofs in Europe. The study was conducted through direct observation of the green roof sites. The researchers examined five sites within different Swiss cantons during the years 2005 and 2006. They focused on two endangered species, the northern lapwing and the ringed plover. The observations were conducted during the breeding season, end of March, until the middle of July. Observations were made once a week with field glasses and field books from a high vantage point. The results were promising in illustrating the utilization of green roofs for nesting habitats. The search was conducted after data showed a decline in bird populations due to increase loss in habitat and fragmentation due to urbanization. The data continues to show some situations in which the northern lapwing actually permanently changed its breeding site to the green roof.

This research provides an incentive to continue gathering more data to incentivize and inform green roof design as an ecologically valuable habitat for bird species. This data can be use to understand that green roof investment is critical to urban environments. These observations show first hand evidence of the benefits that proper green roof design brings. (Figure 8) Image captured by Nathalie Baumann.

Figure 8

02 Scales of Site

City to Block

Scales

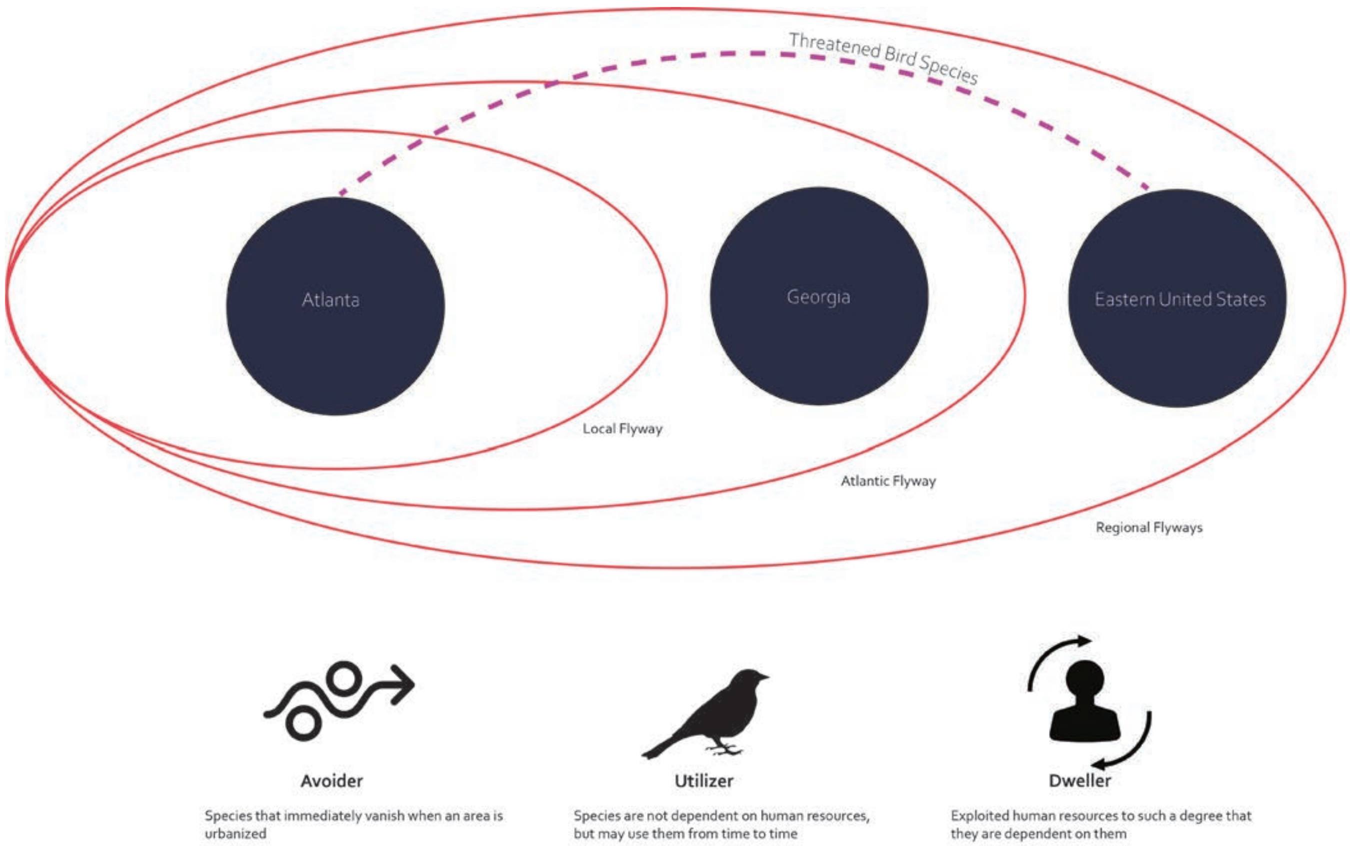
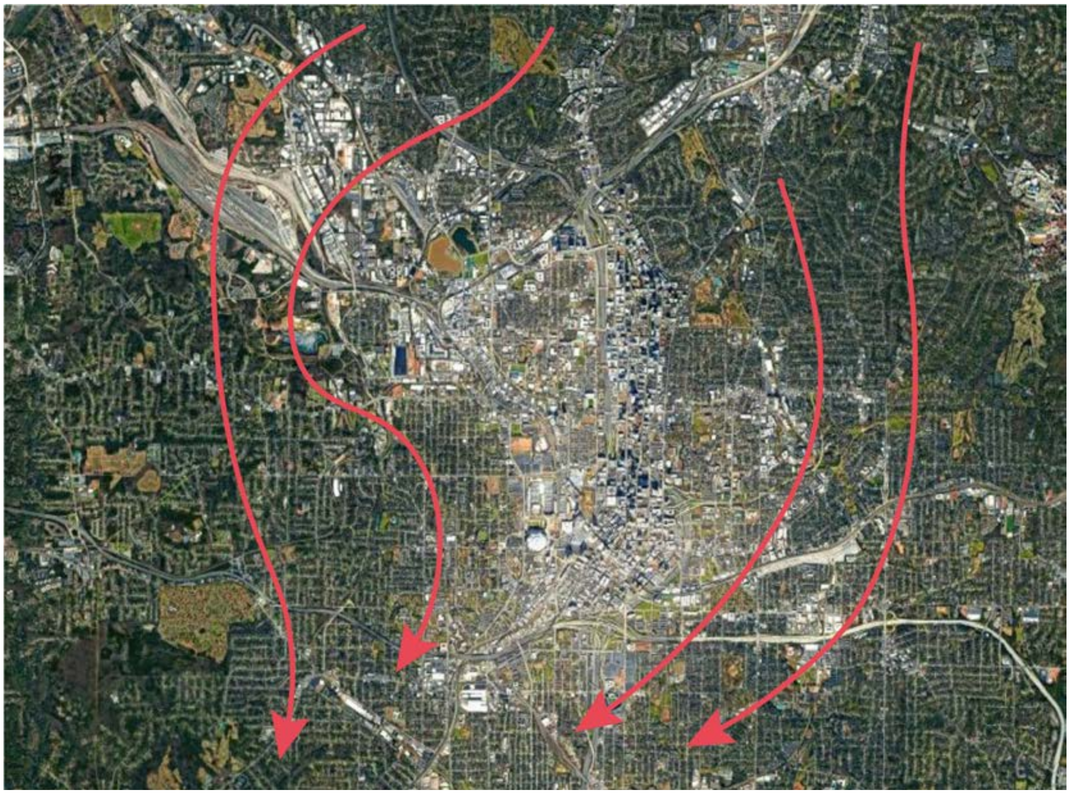


Figure 6

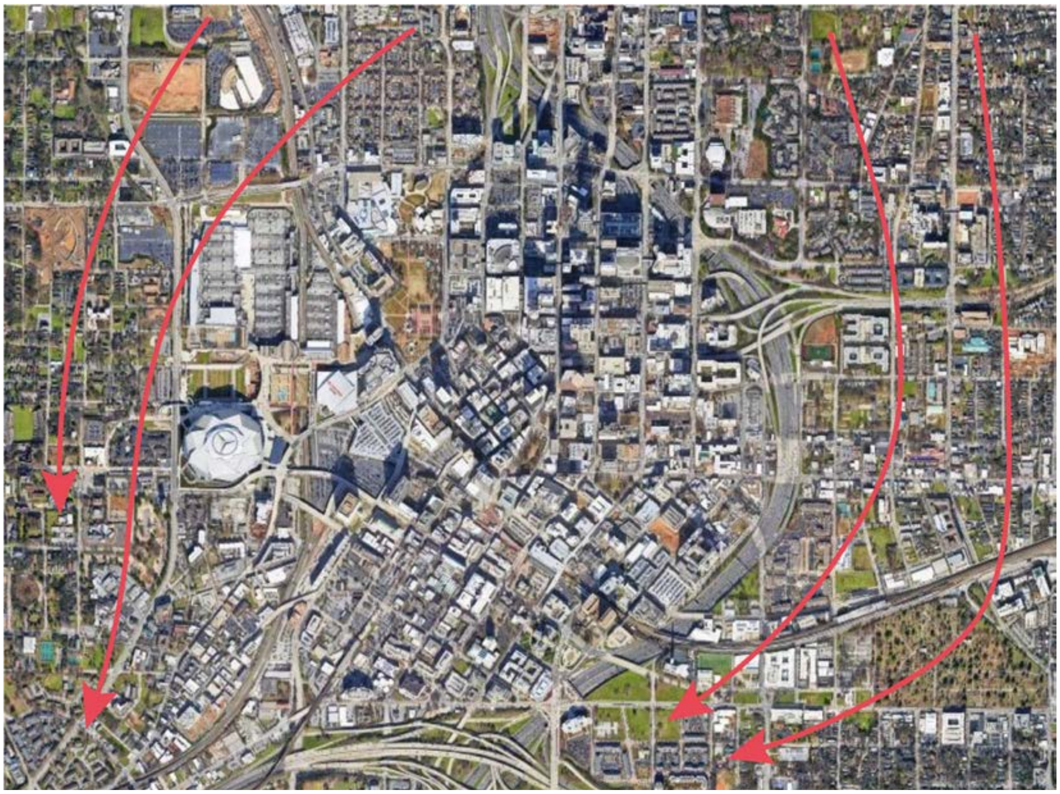
At each scaled approach, the key issues are similar. The homogonization of species is seen at the regional to local scale. Urbanized footprints are becomming increasingly large which has impacted the entire flyway system. Figure 6 is a diagram created to illustrate the issues being within the various scales. The city of Atlanta was selected do to it high levels of urban sprawl, and bringing the project to site design scale.

City Scale



Beginning with the city scale we can see the urbanized footprint from the city of Atlanta. This footprint is a major factor for the avoidance of migratory species within urban areas. This diagram illustrates the general concept of species avoidance.

Downtown Scale



Zooming it to the downtown of Atlanta we can see, at a smaller scale, the same issue. There exists little green space within the downtown area. This causes avoidance of bird species within the downtown area.

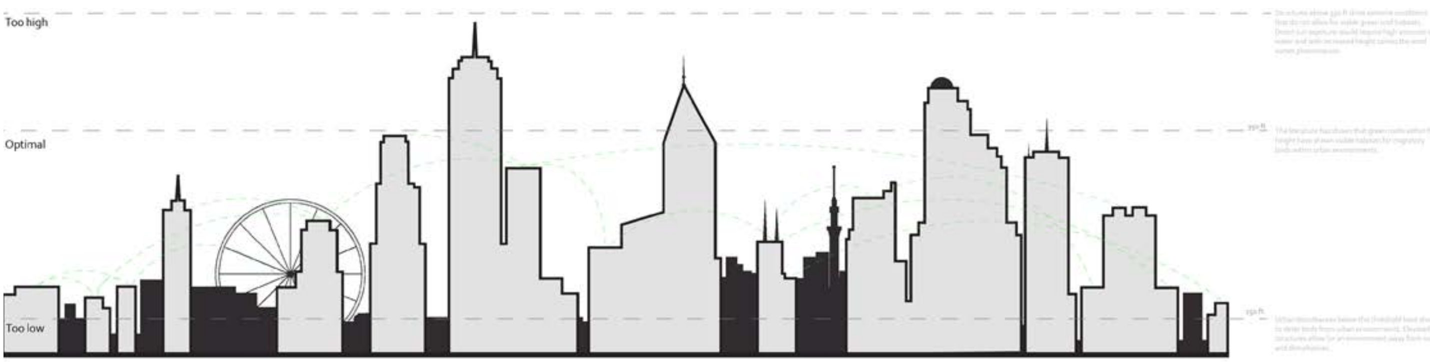
Block Scale

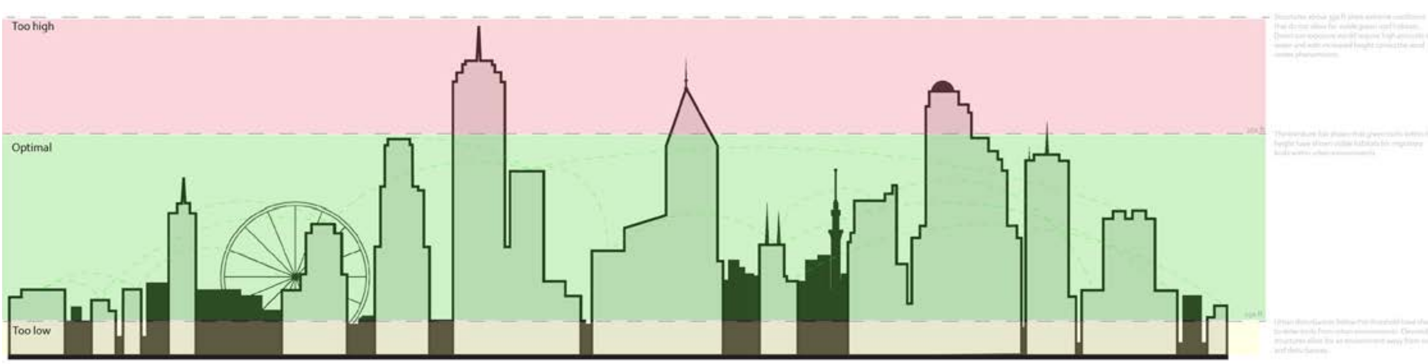
At the final block scale, we can begin to frame the issue into an applicable design scale. This block includes centennial park and linocln park within downtown Atlanta. This site allows for the application of methods found in previous research to create an urban matrix that provedes a viable habtat for bird species within urban cities.

03 Site Criteria

Atlanta City Block

Sectional Criteria





The illustrated section of the Atlanta skyline highlights the parameteres of the criteria for green roof design within urban areas. The parameters are crossed reference with the correlational studies observed as well as the data found in the Midwest Study conducted by Carly Eakin. There exsists an optimal height for green roof implementation. At low levels the levels of disturbance and urban noise is too much for avoider species, and at very high elevations, the conditions are very extreme with high winds and high UV exposure. At optimal heights, the conditions can be ideal for the creation of a migration stopover habitat for some bird species.

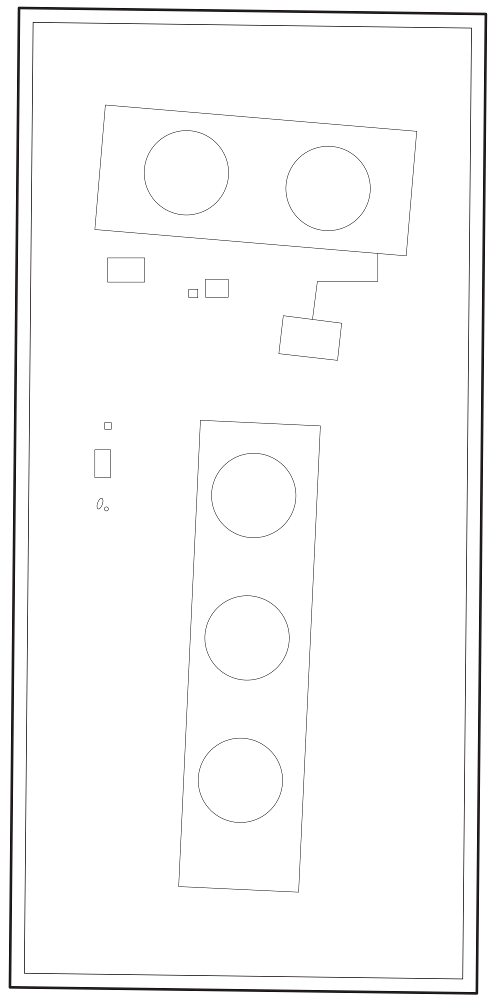
Matrix Block

This diagram highlights the goals of the design project. Based on previous research there exist the opportunity to facilitate migratory birds within urban areas through green roof design. This allows for the opportunity to create an urban matrix between green spaces and hardscapes. Using the parameters of height requirements, the optimal buildings are highlighted above for green roof implementation.

04 Site Design

Sites 3 - 2 - 1

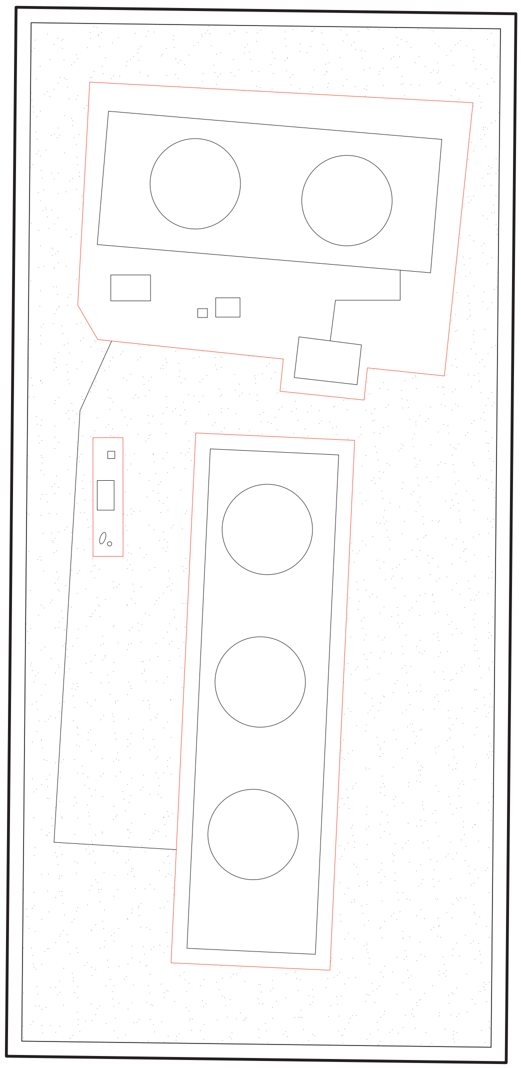
Site 3: GA Department of Health



Existing Conditions

Scale 1/8" = 1'-0"

Existing conditions were drafted for each site. The existing conditions highlight the utilities that are found on the roof top. These particular utilities later define the design parameters for this site design.



Planting Design

Plant Pallette

Bird Targets

Technical Data

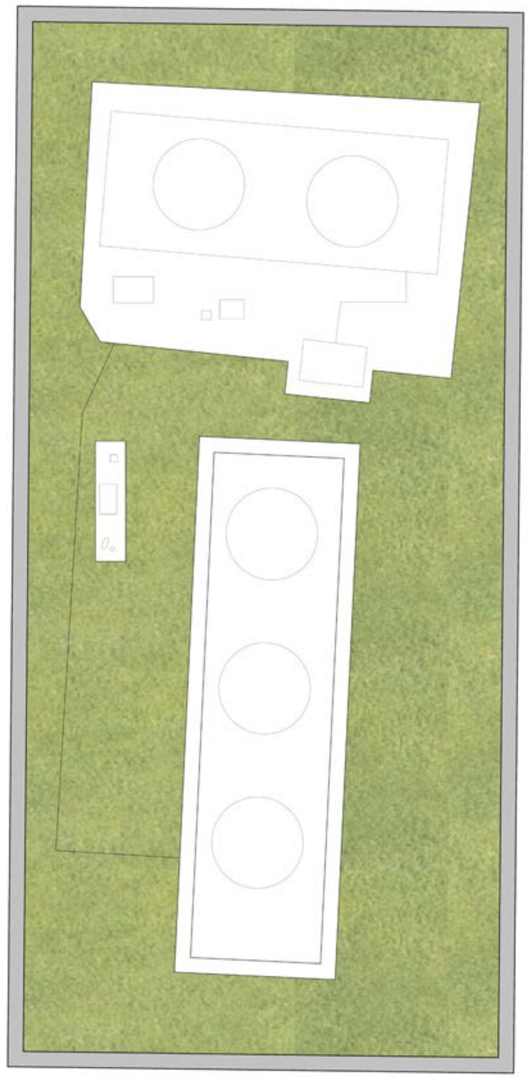
Total Sq. Ft. - 8,742
Seed Mix - 130 seeds per sq. ft. (98% PLS)

Bouteloua gracilis
Koeleria macrantha
Schizachyrium scoparium
Sorghastrum nutans

Scale 1/8" = 1'-0"

Each of the following designs follow the same premise of a three foot offset from the existing utilities. This offset is applied to not disturb or create any issues with the utilities found on these roofs.

This site highlights the base plantings for every site. This plant mix is selected to target utilizer and some avoider species. This grass mix is low maintenance and very durable.

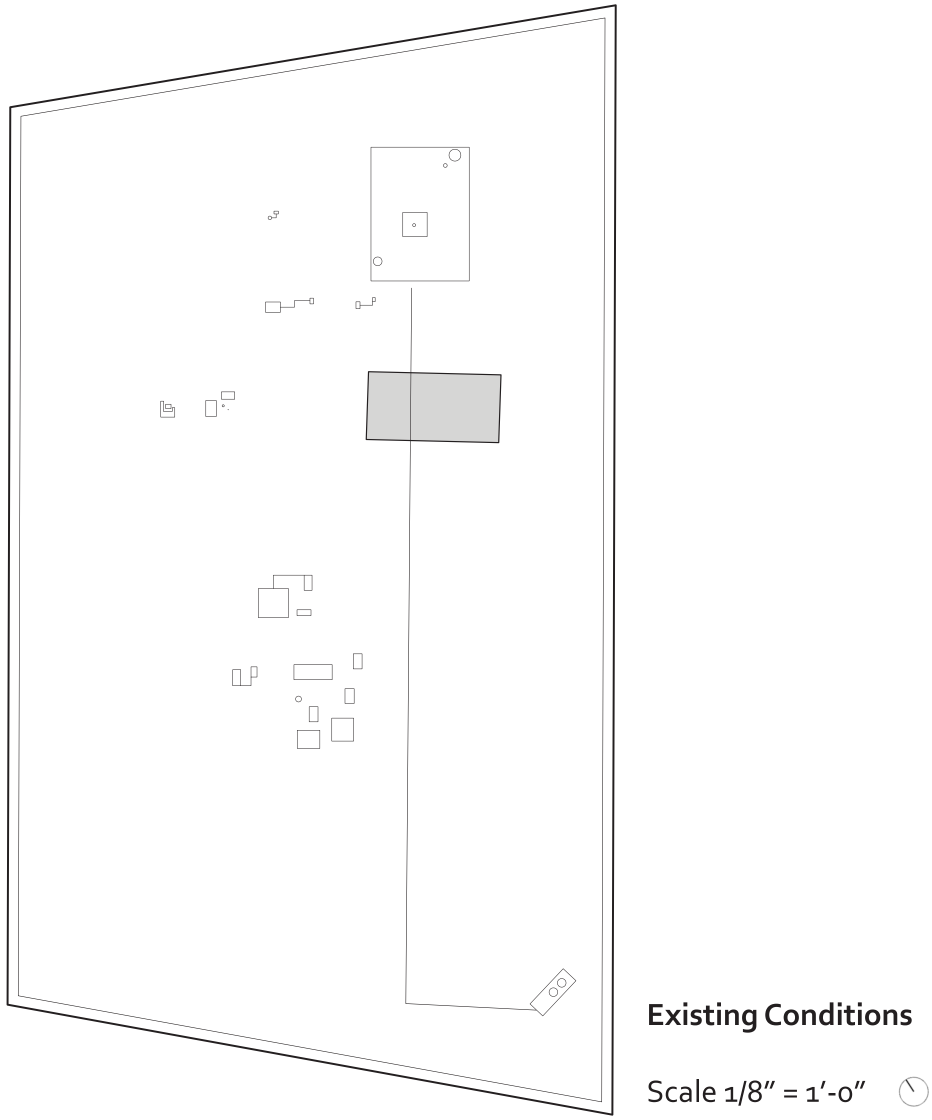


Rendered Site 3

Scale 1/8" = 1'-0"

The render highlights the planting area of the site and what this green roof can begin to look like with the grass plantings.

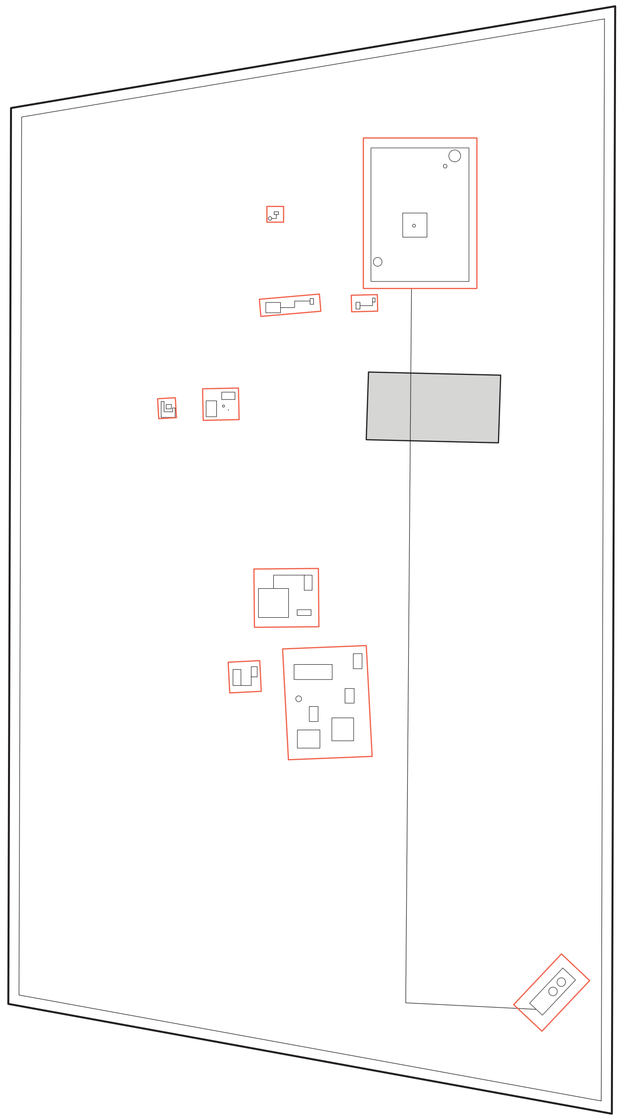
Site 2: 101 Marietta Street



Existing Conditions

Scale 1/8" = 1'-0"

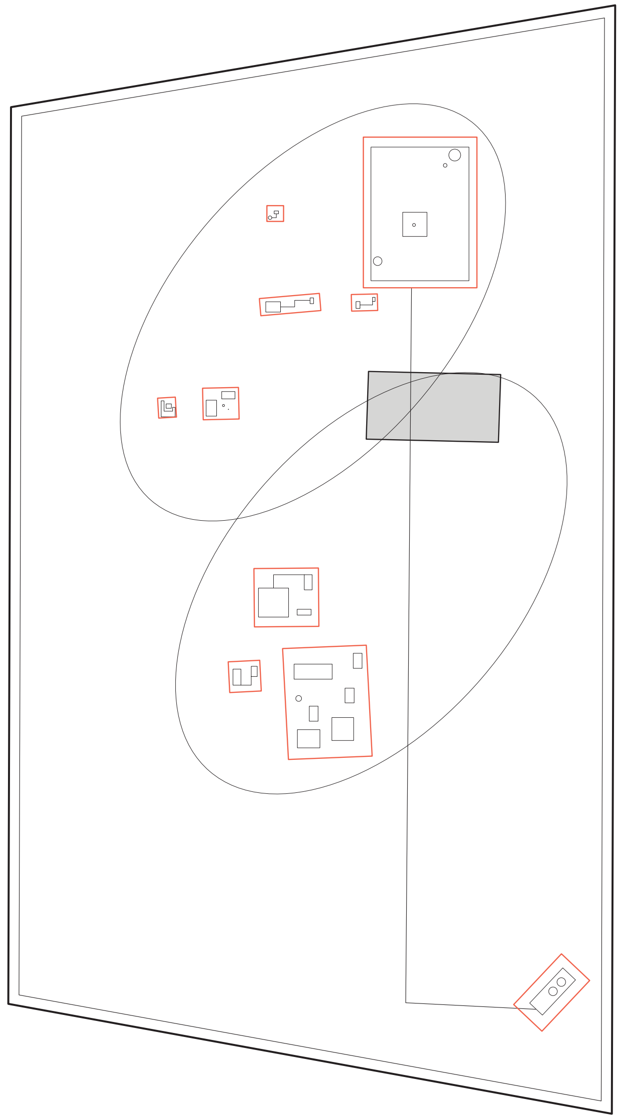
This site was selected based on its limited accessibility. The existing utilities highlighted in this site brought a challenge when moving forward towards a design gesture. The utilities were a mix of antennae and electrical boxes and lines.



Utility Offset

Scale 1/8″ = 1′-0″

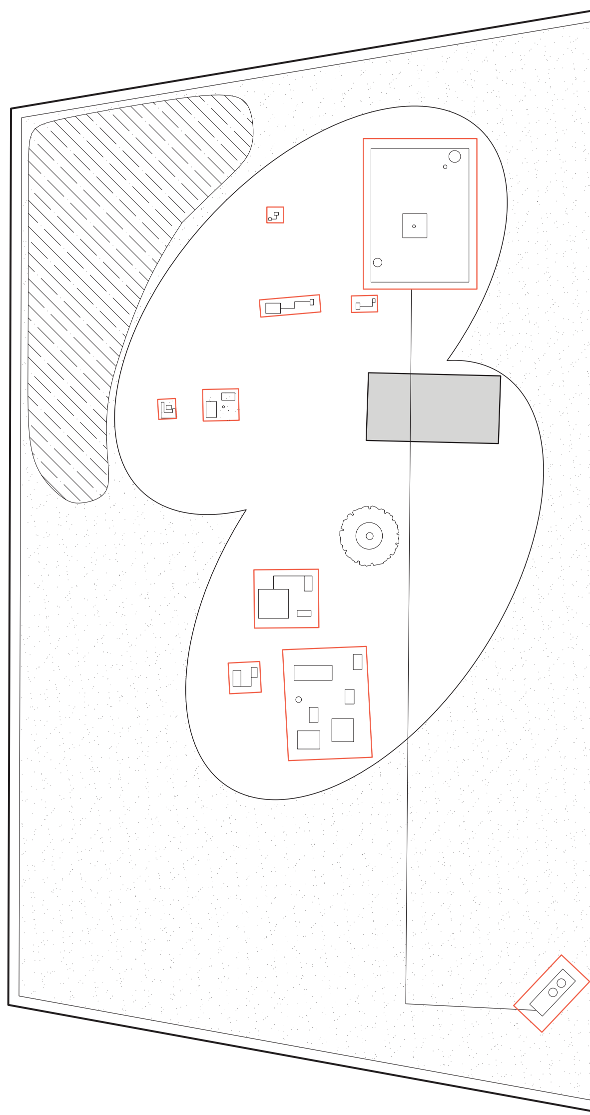
When highlighting the offsets for this site, the challenge increased in finding a rhythm or form that could be derived within the boundaries that the offsets introduce.



Form

Scale 1/8" = 1'-0"

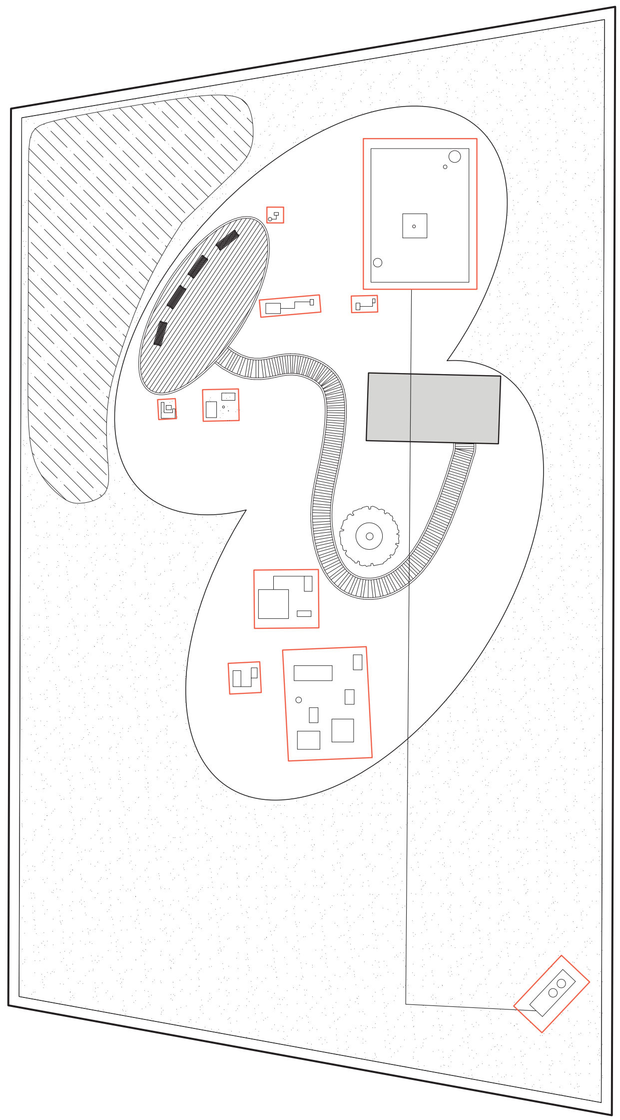
After multiple iterations, a form began to arise within the parameters created. This form brings a gesture that evokes some level of organization and rhythm within the site, outside of the arbitrary, organic form that the offsets create. This form is used to inform the development of the site design.



Planting Beds

Scale 1/8" = 1'-0"

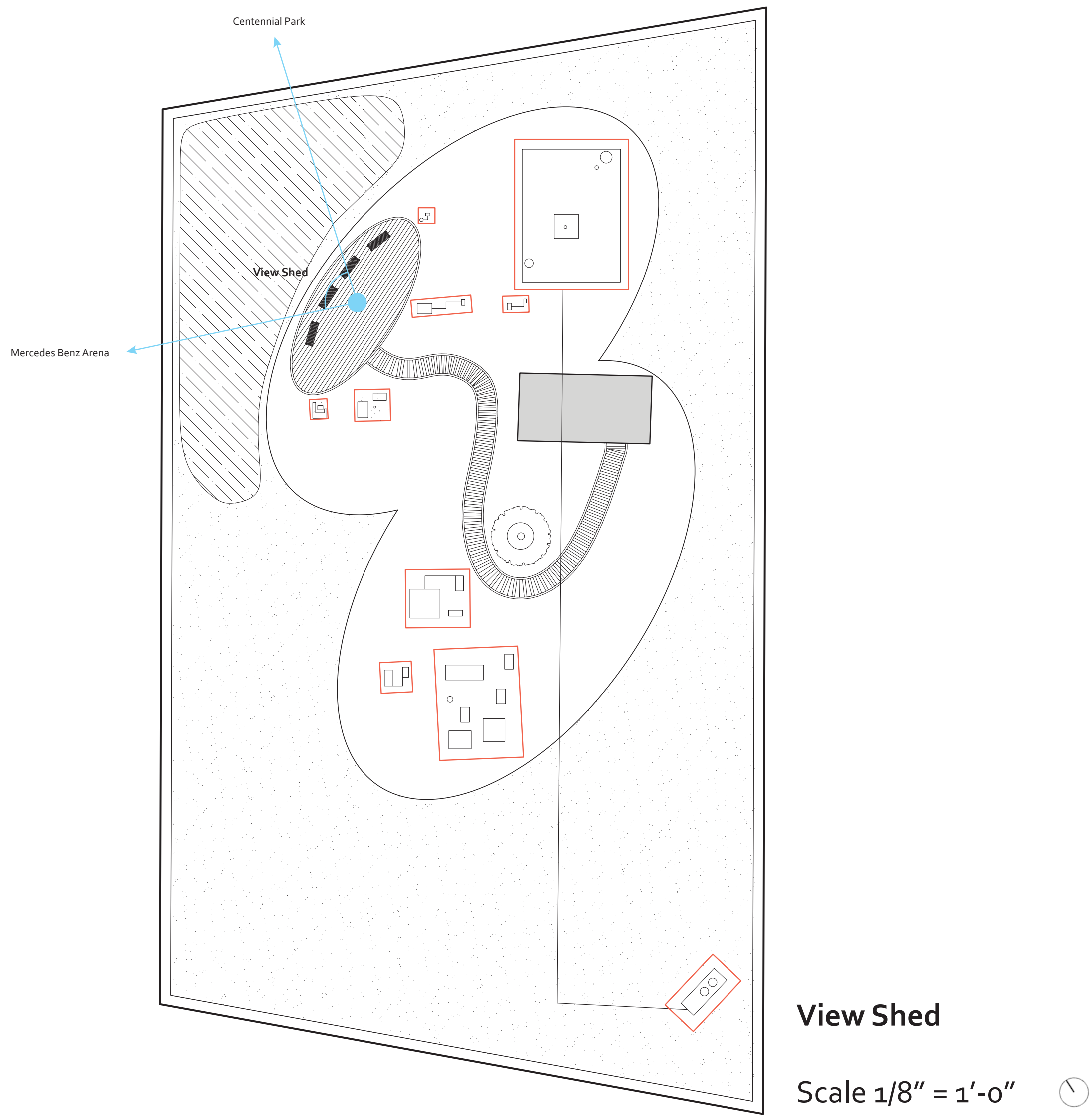
Building on the previous form, the planting bed is a continuation of this gesture. The beds are then applied to maximize the planting area within the parameters set.



Path Form

Scale 1/8" = 1'-0"

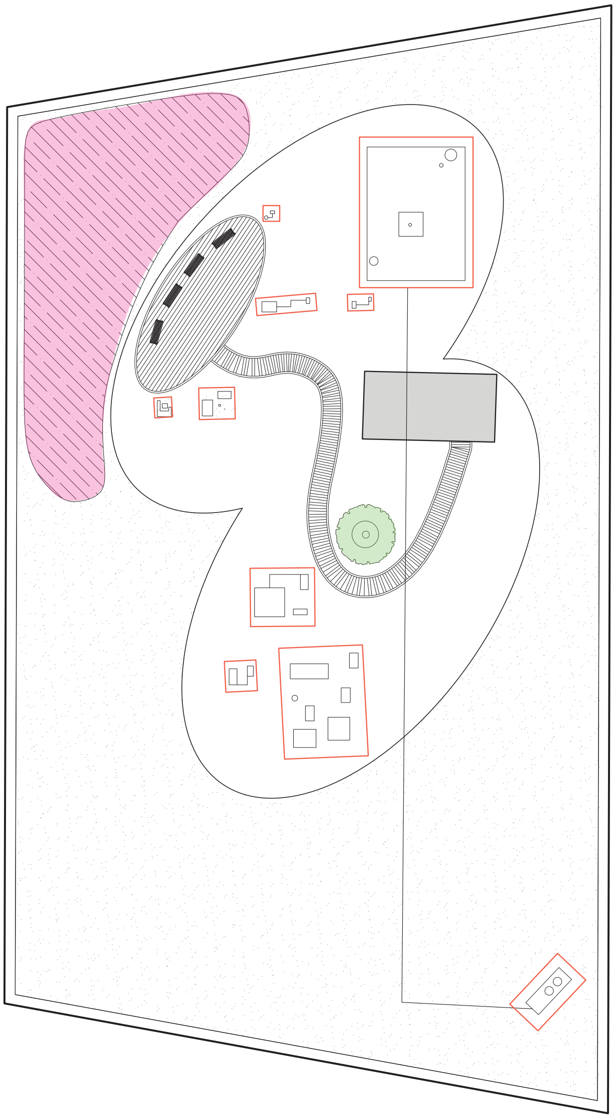
Following the parameter of limited accessibility comes a path design to limit the access to the design. The curves speak to the initial design, in its curvilinear form. The path is built with a steel frame and wood finish.



View Shed

Scale 1/8″ = 1′-0″

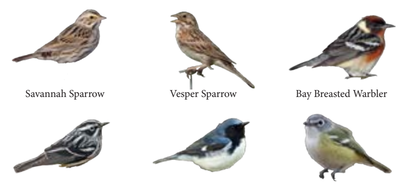
The meandering path leads the user to a powerful view shed. From the view point the user can enjoy the spectacular views of western downtown Atlanta. The most predominant elements of the view would be centennial park and Mercedes Benz arena.



Planting Design

Plant Palette

Bird Targets



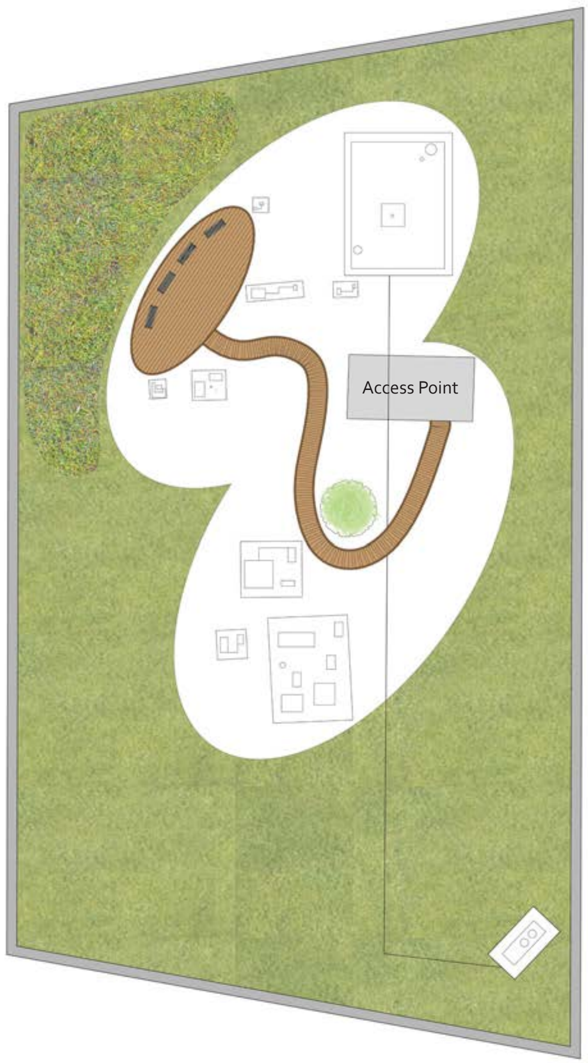
Technical Data

Total Sq. Ft. - 3,962
Seed Mix - 73 seeds per sq. ft. (96% PLS)

Rudbeckia fulgida
Allium cernuum
Anemone patens
Desmodium spp.
Eragrostis spectabilis
Forsythia spp.

Scale 1/8" = 1'-0"

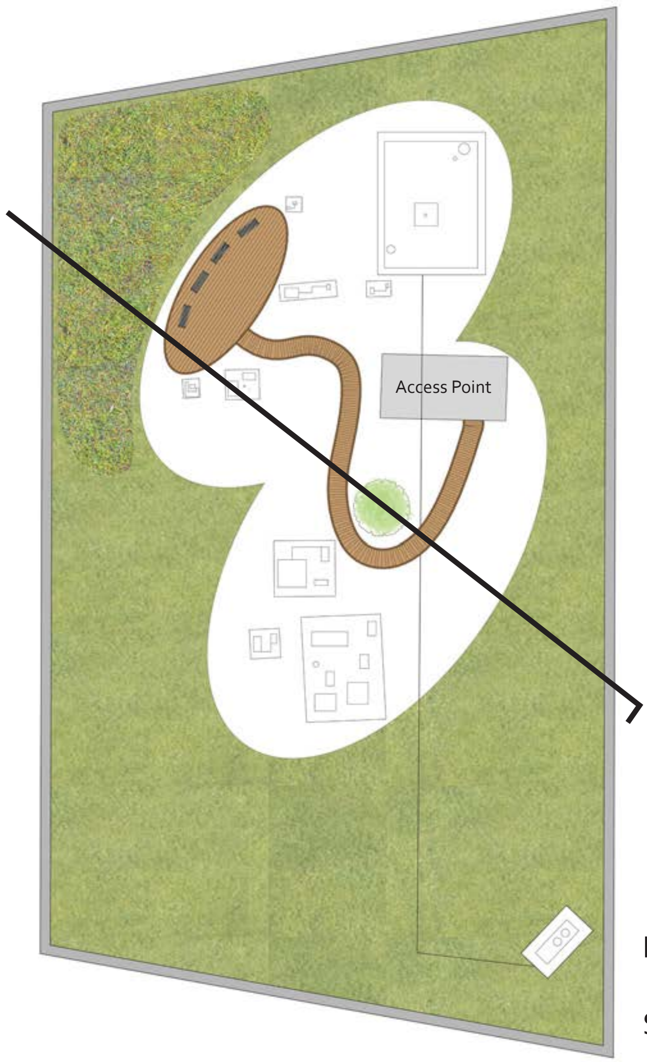
The planting builds of the previous planting with the addition of some flowering plants to enhance the viewing experience for the users visiting the roof. The seed mix attracts birds that have habits of ground foraging.



Rendered Site 2

Scale 1/8″ = 1′-0″

This render begins to illustrate what this design would look like on the roof of the selected site.

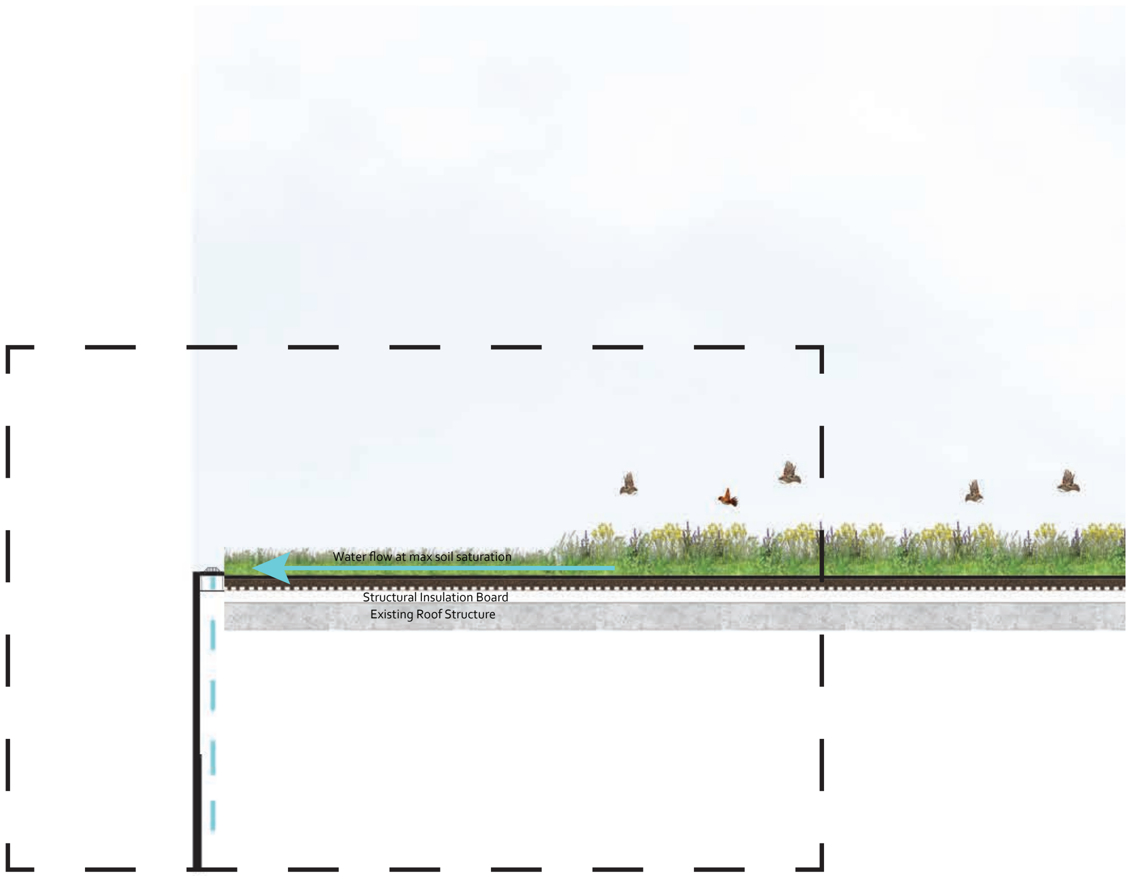


Rendered Site 2

Scale 1/8" = 1'-0"

This section was cut to highlight the character of the site. Also, this section will be used to explain the drainage principles that carry throughout the designs.

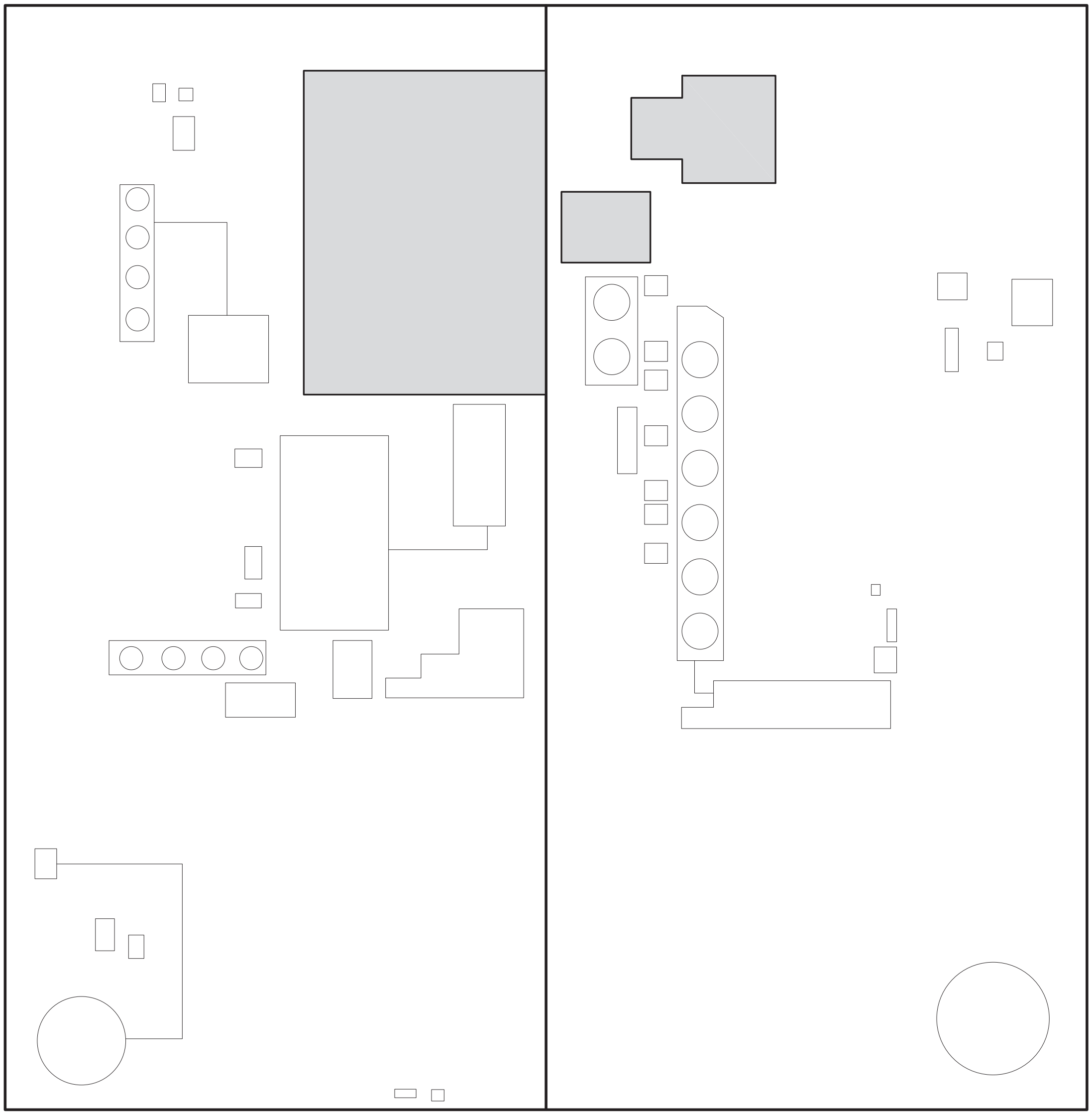
Path Section



This diagram highlights the drainage method on the green roof designs. The dead load of the roof is calculated by the soil at full saturation. This is because once the water reservoir and the soil is fully saturated the water is then carried to the edge of the roof and outlets through a dome roof drain. The water is then processed through the towers drainage system.


Water flow at max soil saturation
Structural Insulation Board
Existing Roof Structure

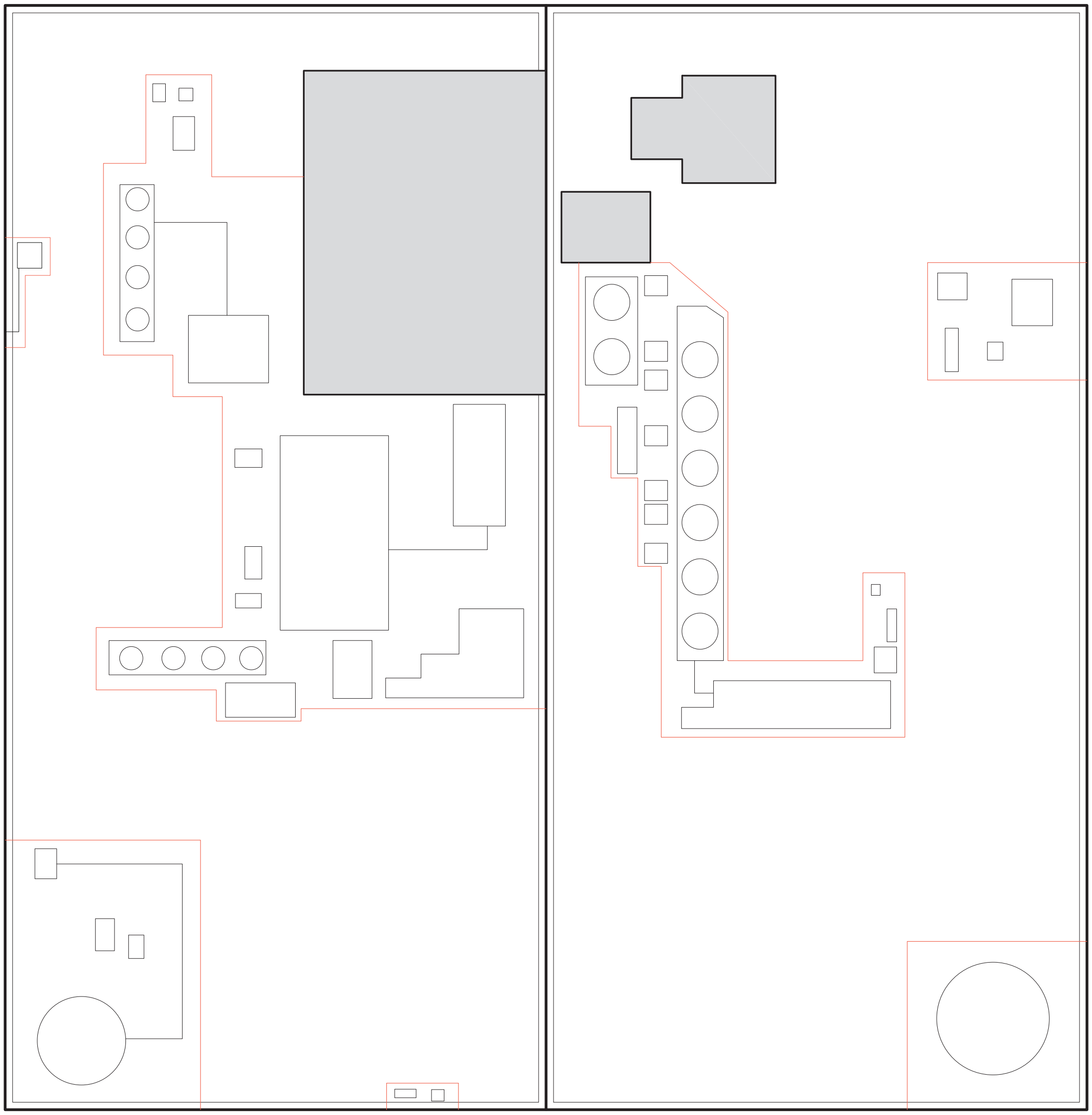
Site 3: Amerimart



Existing Conditions

Scale 1/16" = 1'-0"

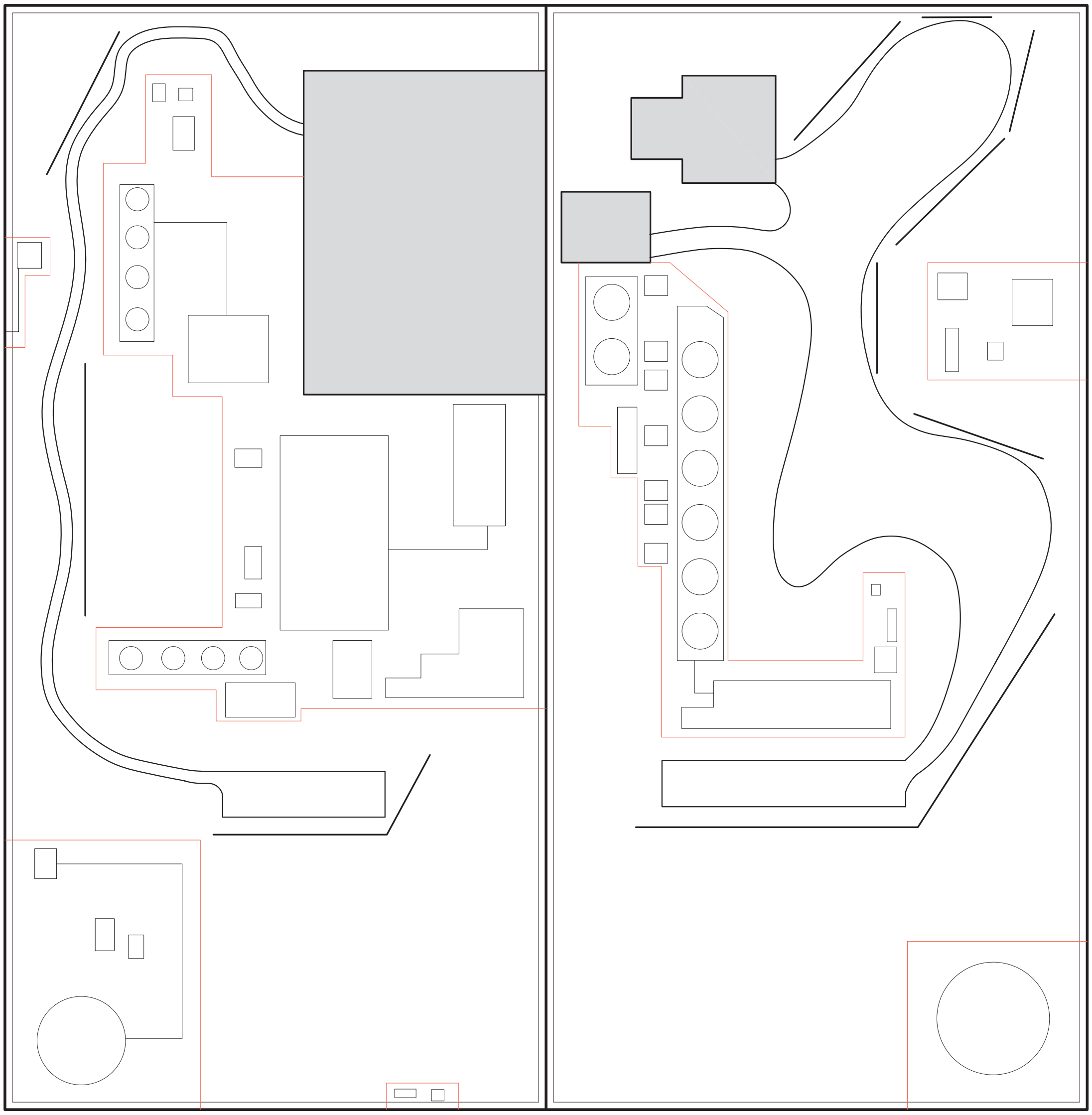
Site 3 is the largest site selection and was selected for the fully accessible condition. This site is designed for user engagement and education in the premise of the green roof designs.



Utility Offsets

Scale 1/16″ = 1′-0″

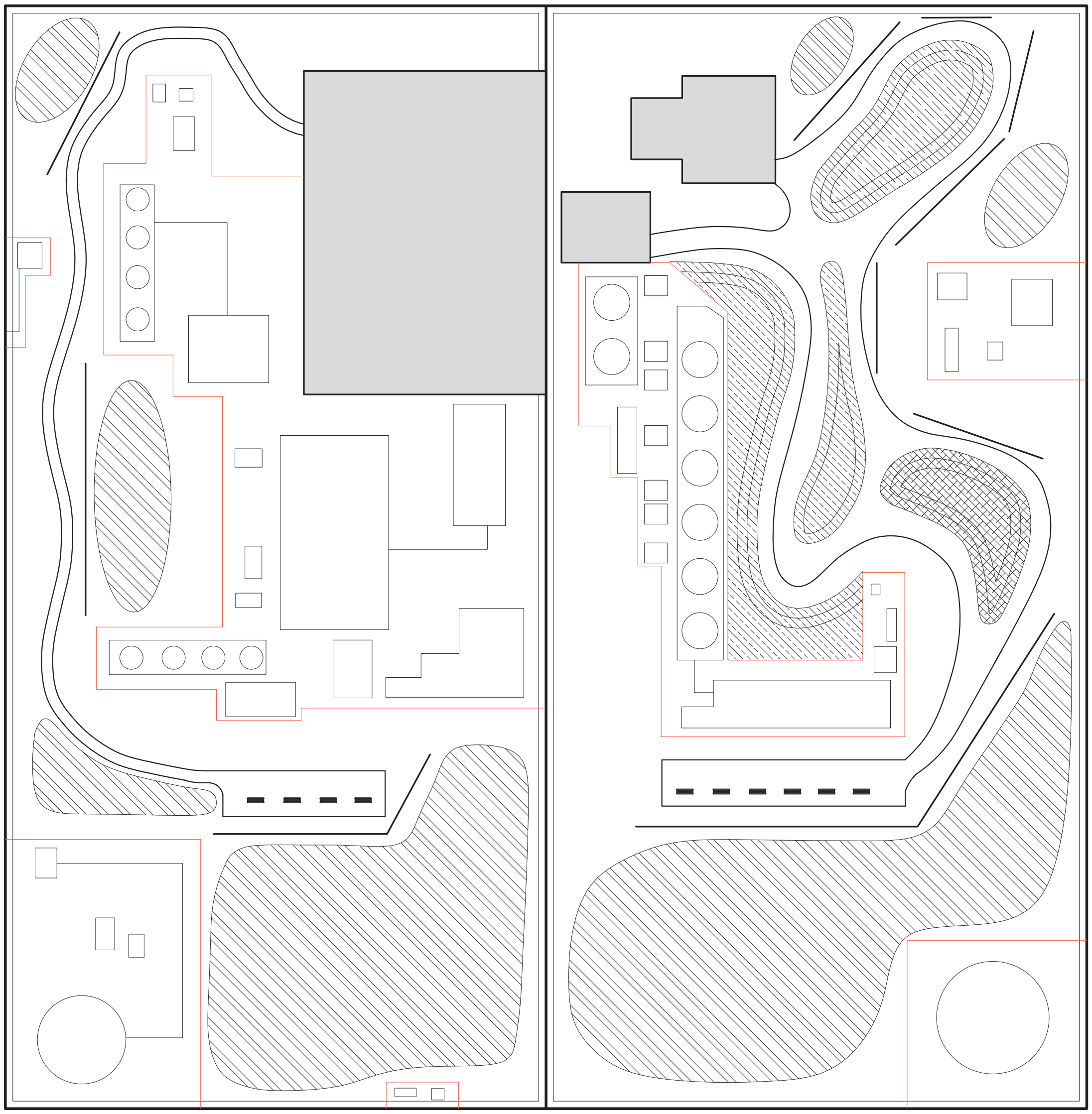
The utility offsets created strict parameters for design. The challenges were multifaceted. The design was to be within the parameters, but also some utilities were quite large and this brought a challenge to hide the utilities from the users.



Path Form

Scale 1/16" = 1'-0"

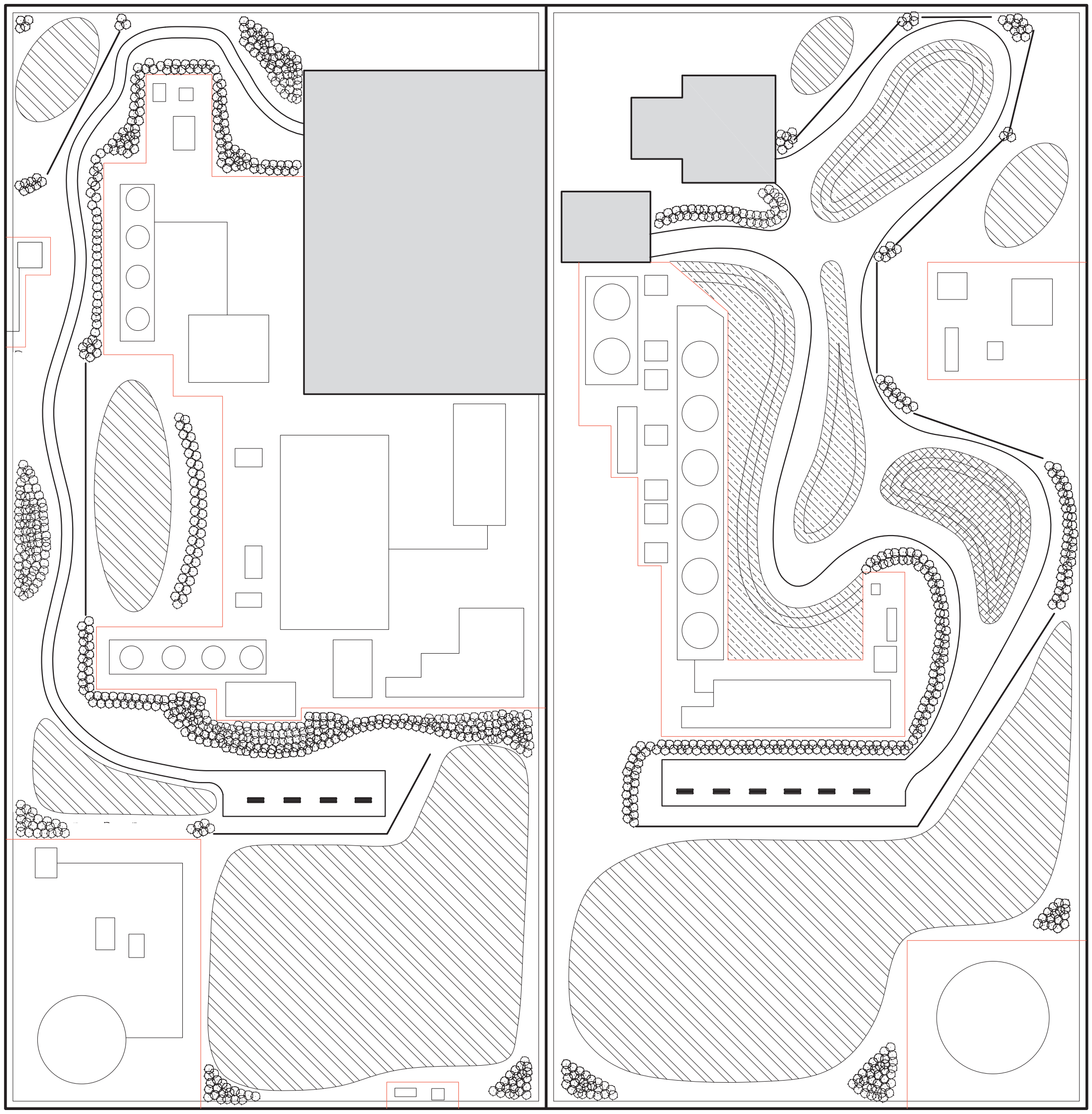
The path forms were created to maximize the use within the created parameters. They fall within the bird blinds which will be explained in a later section. The meandering paths were designed with the influence of Roberto Marx form.



Planting Beds

Scale 1/16" = 1'-0"

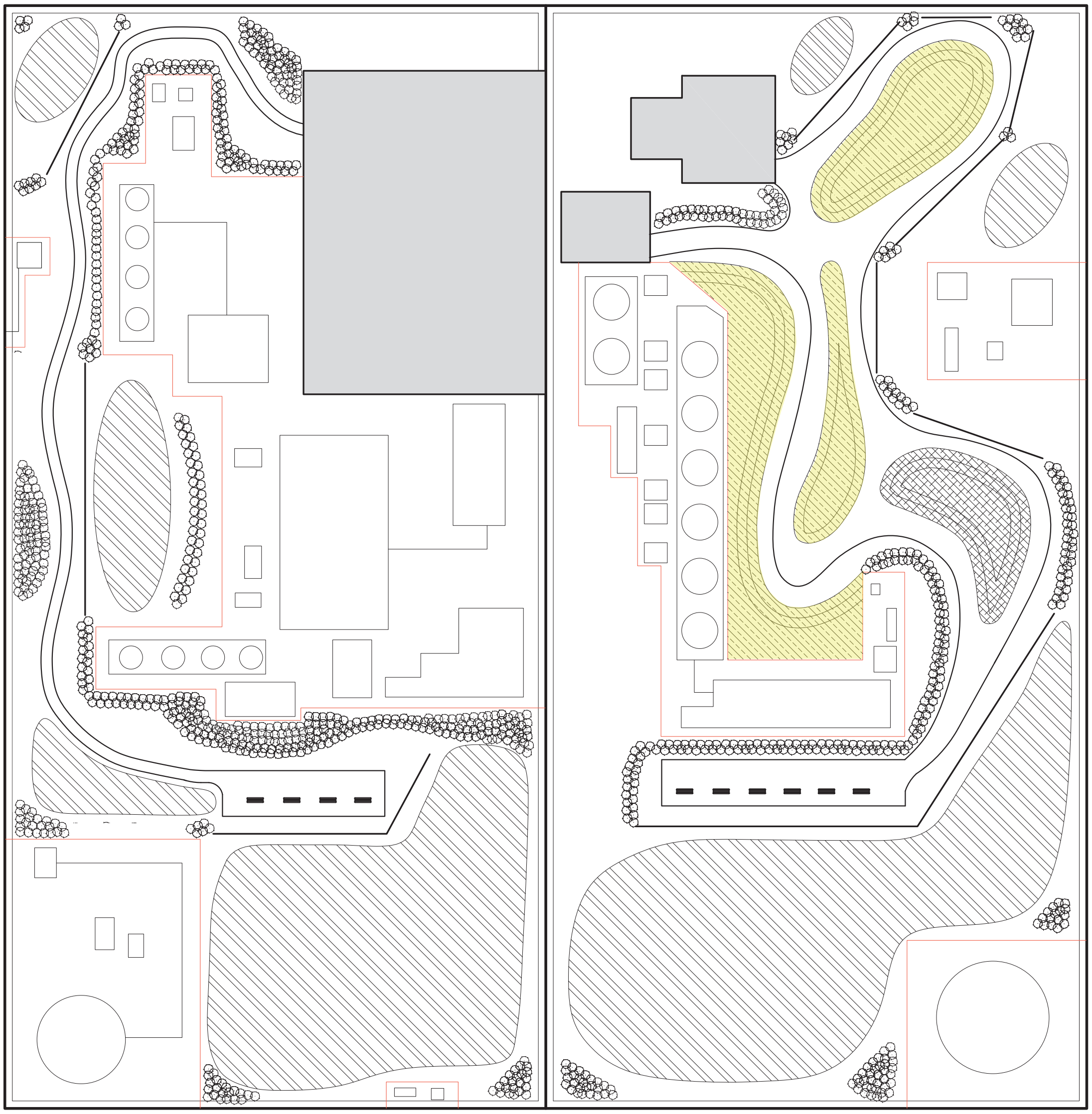
The planting beds are maximized in area within the path and offset limits. The plantings are designed based on species attraction explained later within this section.



Shrub Forms

Scale 1/16" = 1'-0"

The shrub plantings were placed to line paths, break site lines and to frame some views from the site.



Planting Design

Plant Palette




Bird Targets


Bay Breasted Warbler


Black and White Warbler


Black Throated Blue Warbler

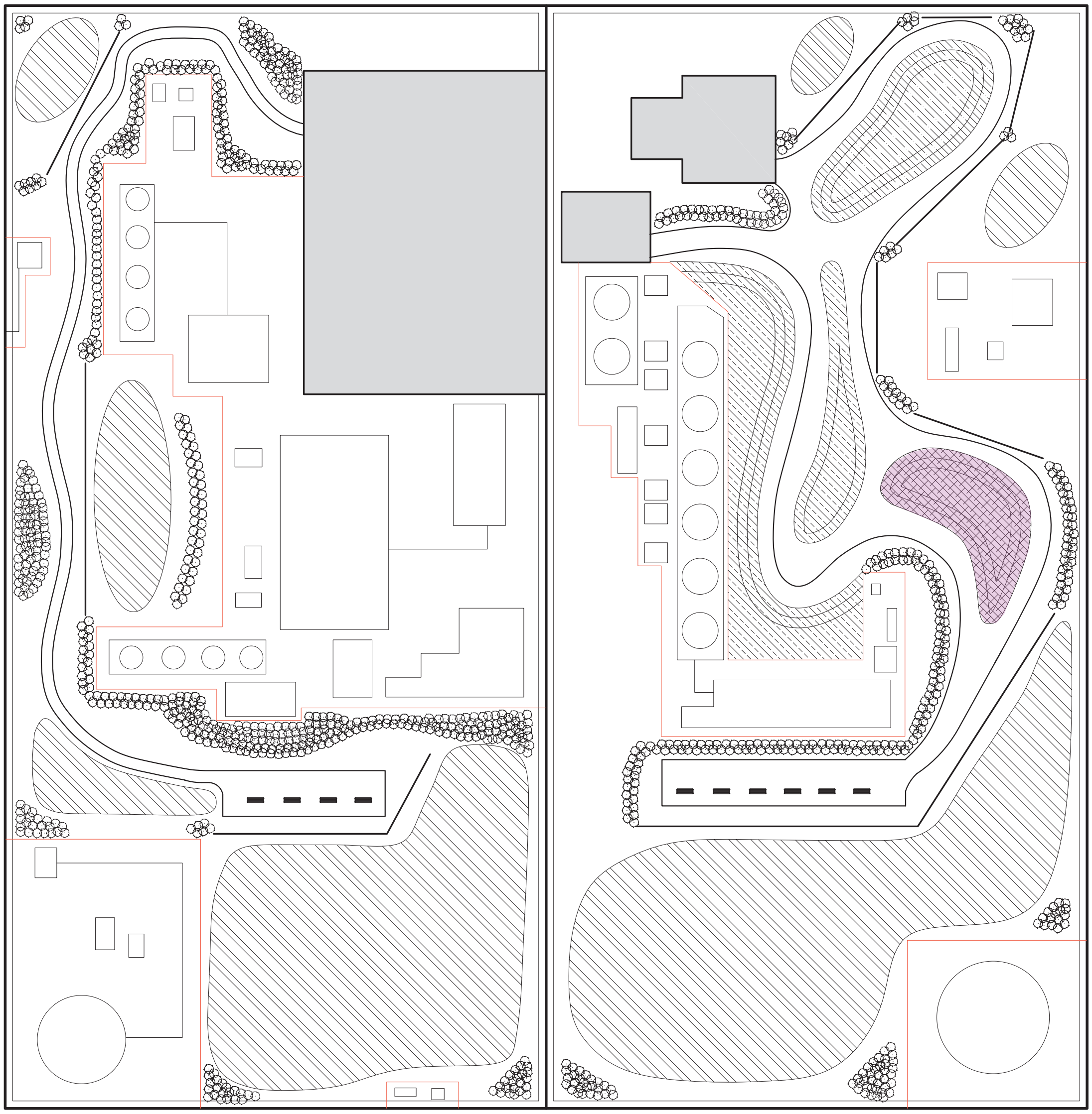
Technical Data

Total Sq. Ft. - 8,366
Seed Mix - 35 seeds per sq. ft. (93% PLS)

Agalanis purpurea
Pycnanthermum tenuifolium
Solidago nemoralis
Anemone patens

Scale 1/16" = 1'-0"

This area of planting was designed to target utilizer species. The flowers attract an array of insects that are within the diet of various utilizer species including, spiders, grasshoppers, lady bugs, among others.



Planting Design

Plant Palette



Bird Targets


Bay Breasted Warbler


Black and White Warbler


Black Throated Blue Warbler


Ruby Throated Hummingbird

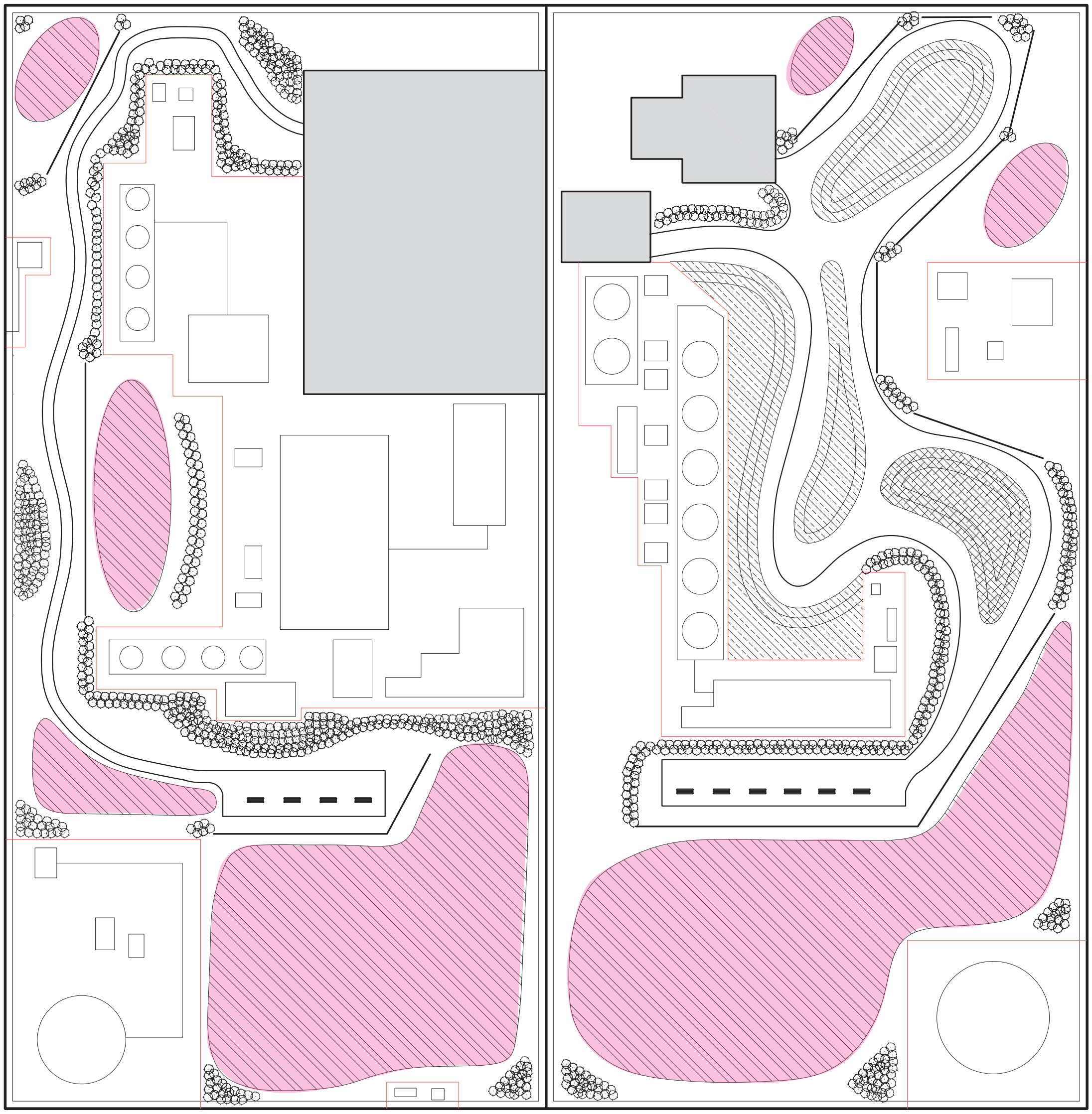
Technical Data

Total Sq. Ft. - 2,138
Seed Mix - 35 seeds per sq. ft. (93% PLS)

Liatris squarrosa
Lespedeza spp.
Schizachyrium scoparium

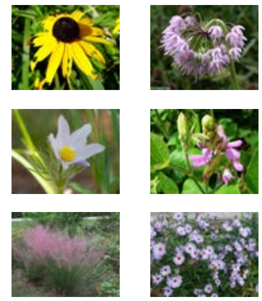
Scale 1/16" = 1'-0"

This area of planting was designed to target species that require nectar producing plants. Specifically the Ruby Throated Hummingbird, which migrates through Atlanta during the summer season.



Planting Design

Plant Palette



Bird Targets

Savannah Sparrow, Vesper Sparrow, Black and White Warbler, Black Throated Blue Warbler, Blue Headed Vireo, Bay Breasted Warbler

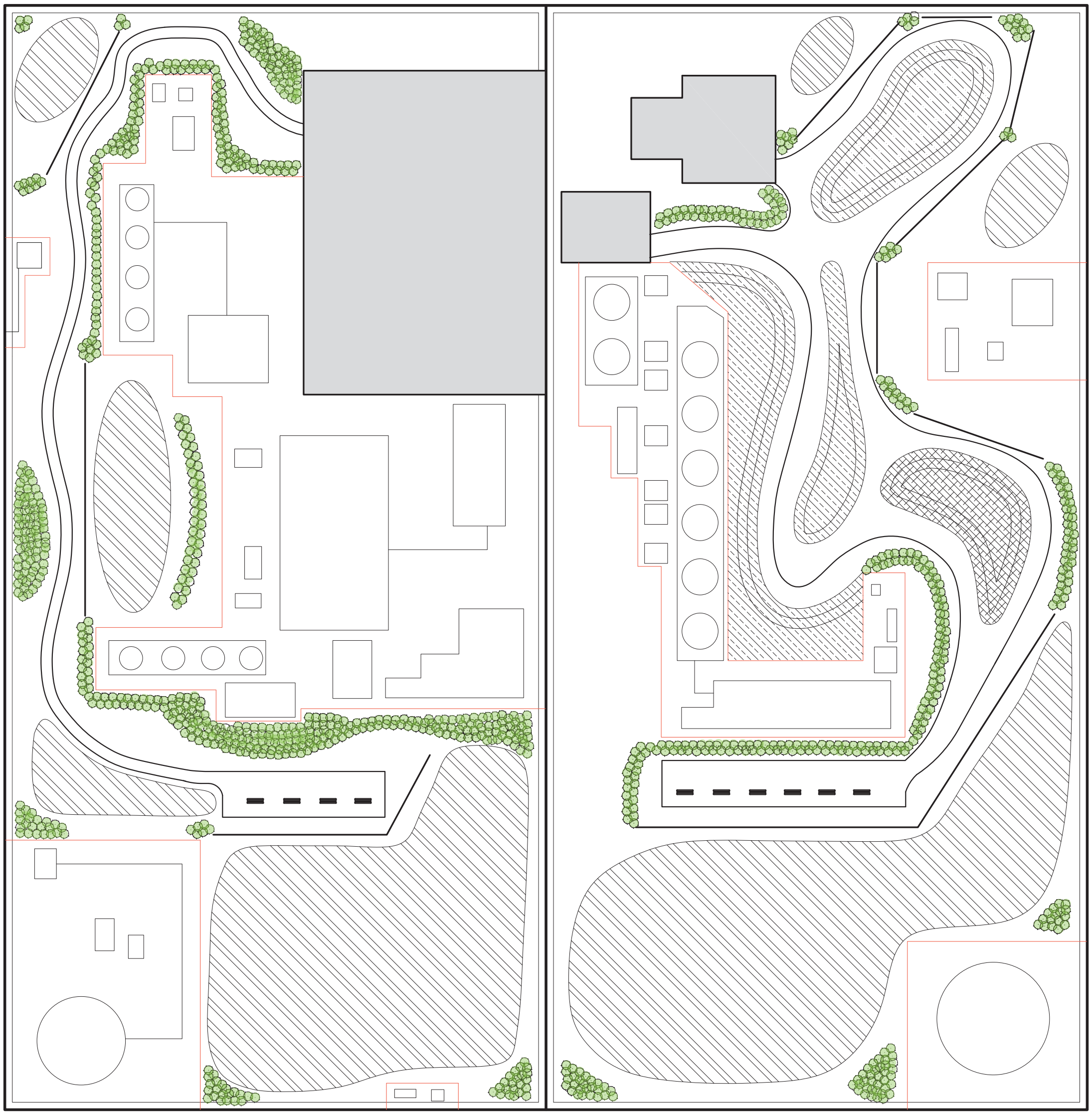
Technical Data

Total Sq. Ft. - 37,454
Seed Mix - 73 seeds per sq. ft. (96% PLS)

Rudbeckia fulgida
Allium cernuum
Anemone patens
Desmodium spp.
Eragrostis spectabilis
Symphyotrichum dumosum

Scale 1/16" = 1'-0"

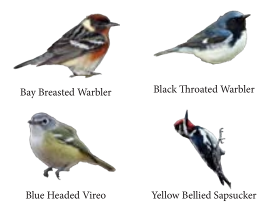
This area of planting was designed to target avoider and utilizer migratory species within this study. The array of flowers attracts a wide variety of insects.



Planting Design

Plant Palette

Bird Targets

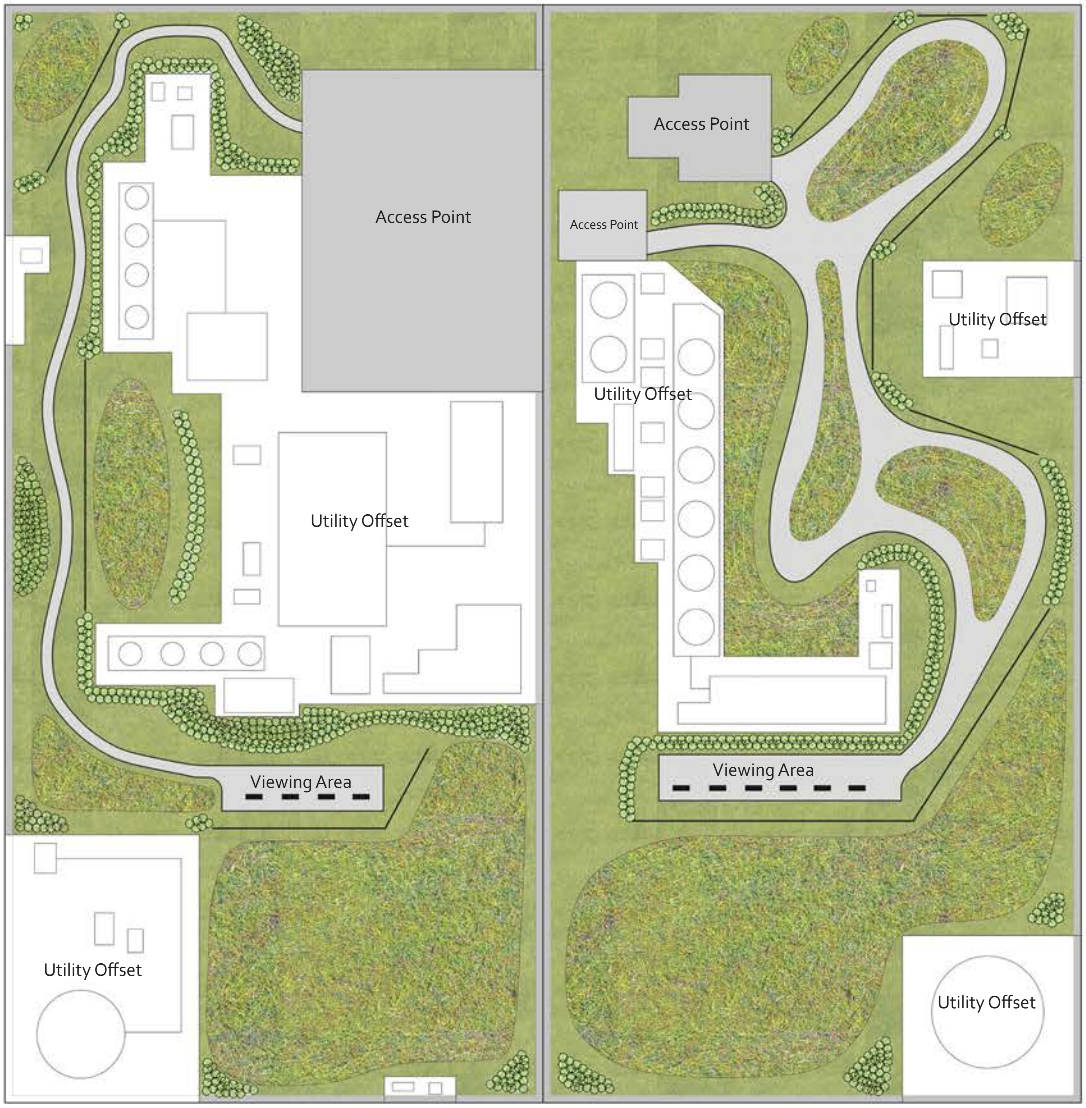


Technical Data

Total Plants - 752
Clethra - 492
Butterfly Bush - 188
Purple lovegrass - 38
Blue grama - 34

Scale 1/16" = 1'-0"

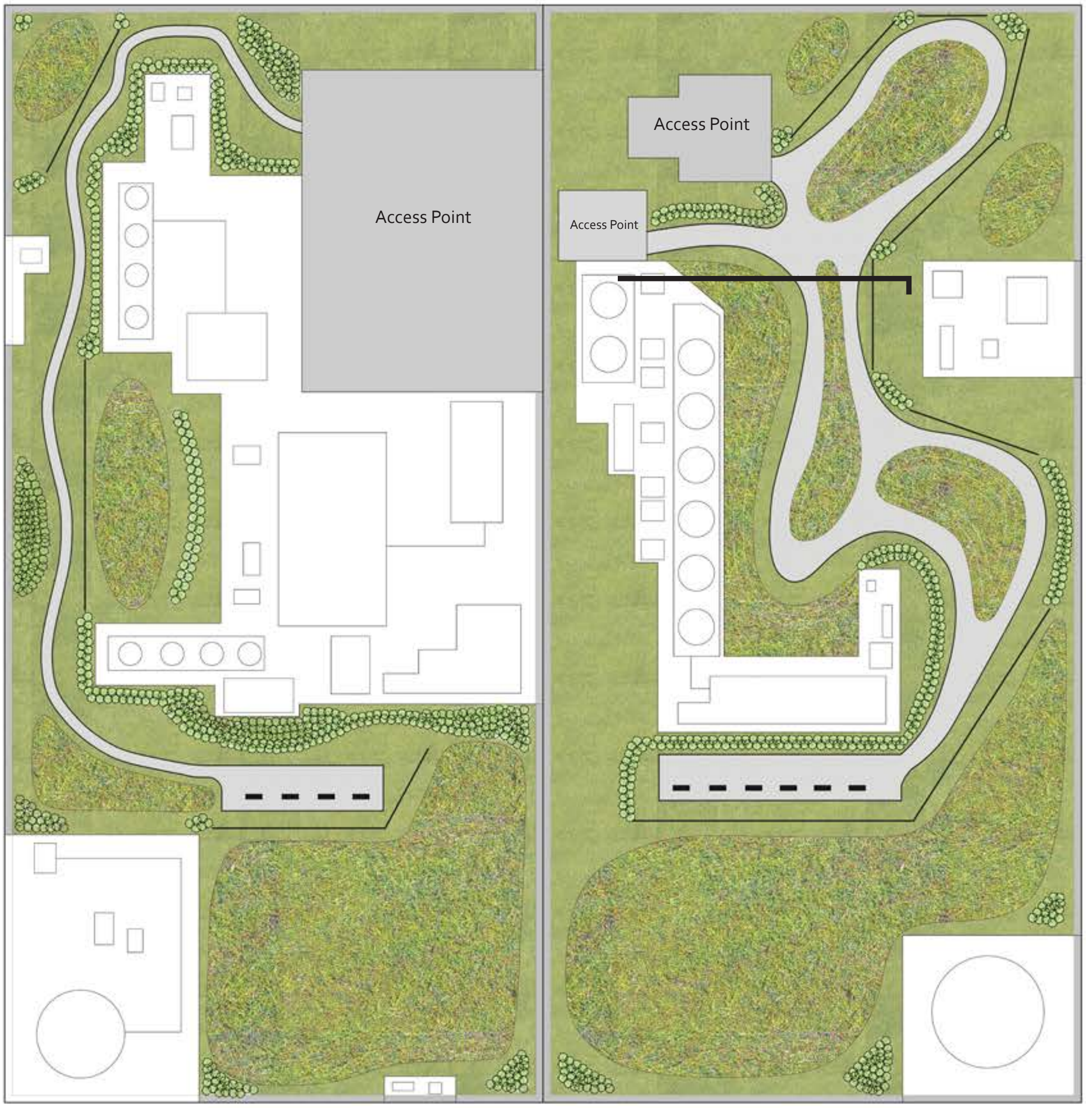
The shrub aesthetic principles were highlighted earlier. The functionality of the shrubs is to create a shelter and a perch for birds. Also, the structure of the shrubs attracts birds characterized as foliage gleaners. The plantings also target the Yellow Bellied Sapsucker which has been tracked around the Atlanta area.



Rendered Site 1

Scale 1/16″ = 1′-0″

The rendered master plan creates the visual of the design and highlights important areas.



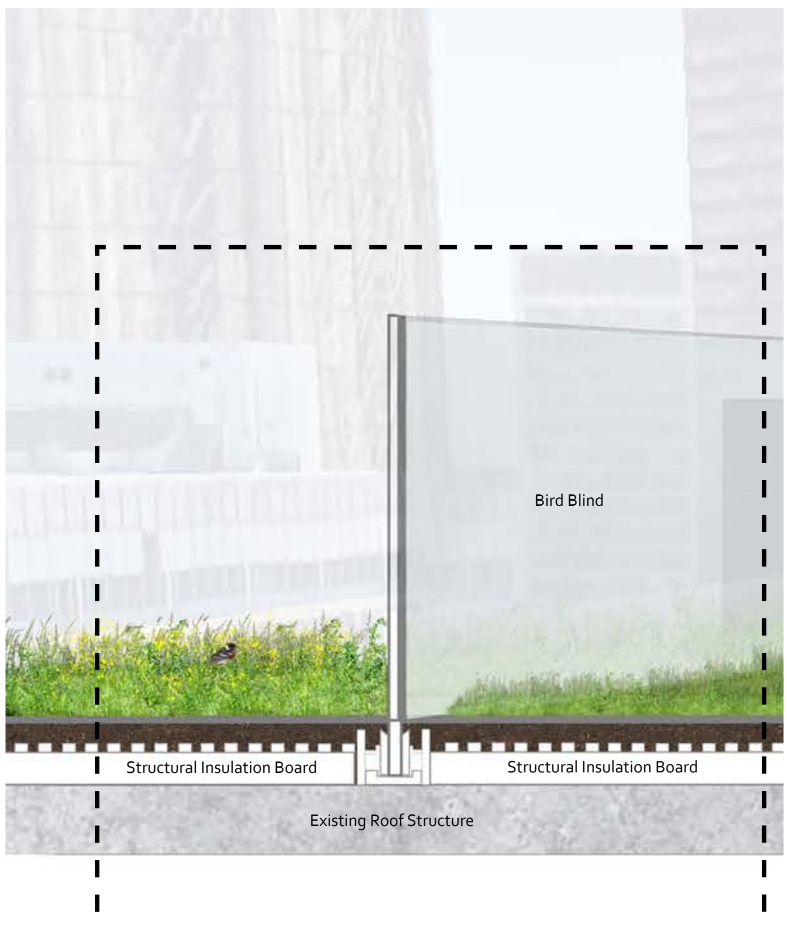
Rendered Site 1

Scale 1/16″ = 1′-0″

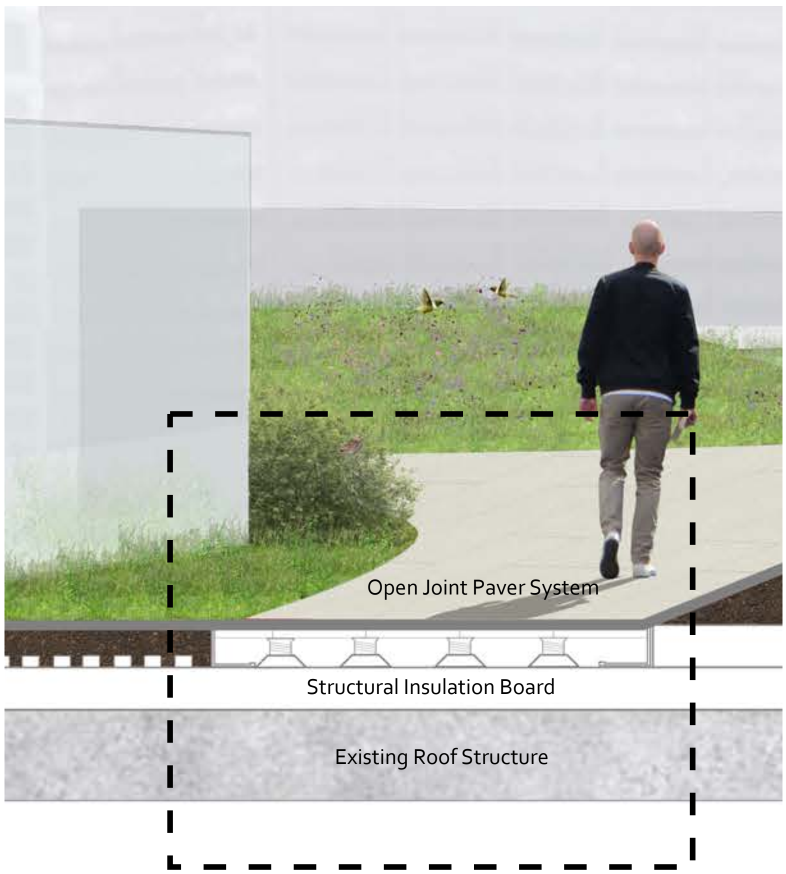
The section cut is similar in criteria as the previous selection. The section will illustrate the character of the site, as well as important constructed features of the site.

Path Section Perspective

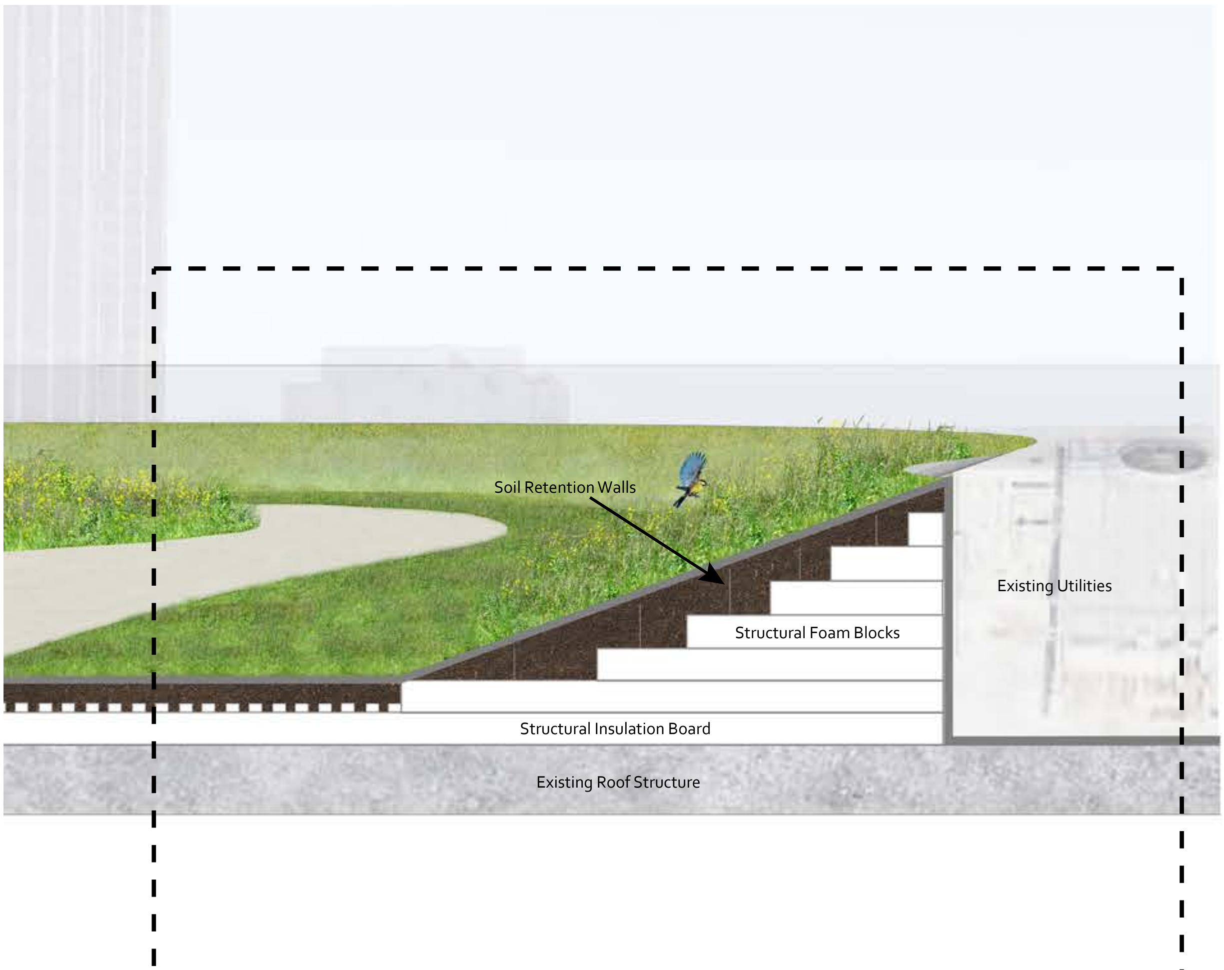
Highlighted are the important areas with regards to key site constructed elements.



One of the key features to this design is the bird blind. Glass was selected for its transparency and structural durability. There are two primary reasons for bird strikes. Either birds believe that they can fly through the surface, or the glass reflects some natural element deceiving the bird into flying into it. These strikes can be avoided by frosting the glass or placing light strips on the glass according to LightsOutGeorgia, an initiative created in Georgia to mitigate bird strikes against towers with glass facades. The bird blind will be anchored to the existing roof structure and secured with two side plates against the base of the glass.



The paver system is an open joint paver system. This system information is provided by HydroTech, a Sika Company. American Hydrotech offers a wide variety of finishes and dimensions. Most notable project as precedent was the Mercy Hospital in Illinois. This system is created using a pedestal system that the pavers attach too. Allowing for flexibility in design and superior drainage under the paver system.



The final system is the artificial mounds created to block the sight of the existing utilities. The structural insulation board works as the foundation for this structure. Above this board, structural foam blocks are places to create the general form of the mound. These pieces are attached with a polyurethane adhesive. On this structure, soil retention walls are place (provided by HydroTech) to retain the soil placed on the mound. The structure can mitigate erosion up to a 45 degree angle. Staying within those parameters, the utilities can be covered within the site design.


Bird Blind
Open Joint Paver System
Structural Insulation Board
Structural Insulation Board
Structural Insulation Board
Existing Roof Structure
Existing Roof Structure
Soil Retention Walls
Structural Foam Blocks
Existing Utilities
Structural Insulation Board
Existing Roof Structure

Target Bird Species

Bird migrations through Atlanta occur during the Spring (March 15th - May 31st) and Fall (August 15th - November 15th) periods. The foliage gleaners include Blue Headed Vireo, Bay-Breasted Warbler, and the Black-Throated Blue Warbler. They have primarily all insect diets. The ground foragers include the Savannah and Vesper Sparrow. These bird species enjoy larger insects such as spiders and grass hoppers along with seeds in the winter period. The Ruby Throated Hummingbird is the only nectar loving bird and typically dwell in Atlanta during the summer months. The Yellow Bellied Sapsucker and the Black and White Warbler are the two bark foragers that enjoy the shrub plantings. All target species follow typical migration patterns, with the exception of the Yellow Bellied Sapsucker which is a winter resident in Atlanta.

Planting Pallete

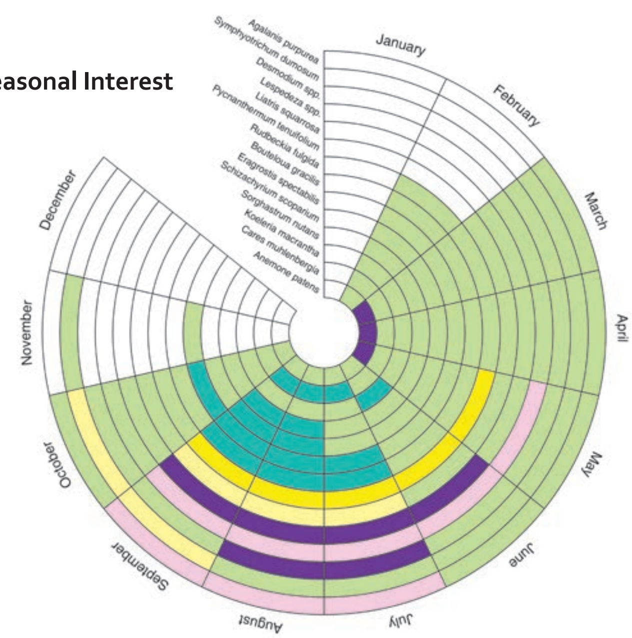
Flowers:

1. *Desmodium spp.*
2. *Rudbeckia fulgida*
3. *Lespedeza spp.*
4. *Allium cernuum*
5. *Anemone patens*
6. *Liatris squarrosa*
7. *Agalinis purpurea*
8. *Pycnanthermum tenuifolium*
9. *Solidago nemoralis*
10. *Symphyotrichum dumosum var. dumosum*

Grasses:

1. *Koeleria macrantha*
2. *Eragrostis spectabilis*
3. *Sorghastrum nutans*
4. *Bouteloua gracilis*
5. *Schizachyrium scoparium*
6. *Cares muhlenbergia*

Seasonal Interest



05

Conclusion

Outcomes

Conclusion

The premise of this research and design is to target migratory birds flying through the city of Atlanta. Recent innovations in technology has grounded this theory and shows promise to further opportunities throughout many urban areas. The literature continues to highlight the opportunity to create green roof habitats outside of the typical sedum roofs (Sutton et. al. 2012). This project creates 77,548 sq. ft. of planted habitat with 8 target species. The design includes 16 native plant species. The research conducted supports the premise in facilitating migratory birds through the creation of stop over migratory habitats. The results in design can be scaled by many factors including, but not limited to, similar species attraction within bird families, and multiple plantings to attract various insect species. There still needs to be more research conducted to explore more opportunities to create a matrix between the urban fabric and the flyway systems. As sprawl continues to occur throughout the United States, and many large cities throughout the world, it is critical to create these habitat system to compensate for so much prairie habitats that have been lost.

References

American Society of Landscape Architects. (2021). ASLA Green Roof. Retrieved from https://www.asla.org/greenroof/index.html

Abueish T., P. (2018), Middle East's largest living green wall unveiled in Dubai, retrieved from <https://gulfnews.com/uae/environment/middle-easts-largest-living-green-wall-unveiled-in-dubai-1.2231920>
Bird Life International. (2011) Data Zone. Retrieved from http://datazone.birdlife.org/ userfiles/file/sowb/flyways/3_Atlantic_Americas_Factsheet.pdf

Baumann, N. (2006). Ground-Nesting Birds on Green Roofs in Switzerland: Preliminary Observations. University of Applied Sciences Wadenswil. Wadenswil, Switzerland.

Blanc P., P. (2006) The Vertical garden, from nature to cities – a botanical and artistic approach by Patrick Blanc, viewed September 15, 2020, <hhtp://www.verticalgardenpatrick blanc.com/>

Brenneisen, S. (2004). Green roofs-how nature returns to the city. Acta Hortic 643:289–293

Brenneisen, S. (2006). Space for urban wildlife: designing green roofs as habitats in Switzerland. Urban Habitats 4:27–36

Bricklin, R. B. (2016). Bird migration through an urban landscape: Stopover site selection, associations with native and non-native plants, and stress hormone levels (Order No. 10125235). Available from ProQuest Dissertations & Theses Global; SciTech Premium Collection. (1807959217). Retrieved from http://libproxy.clemson.edu/login?url= https://www-proquest-com.libproxy.clemson.edu/dissertations-theses/bird-migration-through-urban-landscape-stopover/docview/1807959217/se-2?accountid=6167

Cantor SL (2008) Green roofs in sustainable landscape design. WW Norton and Company, New York.

Condon, E. (2015). The effect of urbanization on the stopover ecology of neotropical migrant songbirds (Order No. 1591097). Available from ProQuest Dissertations & Theses Global. (1696068765). Retrieved from http://libproxy.clemson.edu/login?url=https://www-proquest-com.libproxy.clemson.edu/dissertations-theses/effect-urbanization-on-stopover-ecology/docview/1696068765/se-2?accountid=6167

Conole, L. (2015). Deconstructing urban tolerance: a bird's-eye view. Australia. University of Tasmania, Australia.

Eakin, C., et. Al., (2015). Avian Response to Green Roofs in Urban Landscapes in Midwestern USA. Wildlife Society Bullitin.

Environmental Protection Agency, (2012), Climate change: Human impacts and adaptation. Retrieved from http://www.epa.gov/climatechange/impactsadaptation/ coasts.html#impactssea

Evans, K., S. Newson, and K. Gaston. (2009). Habitat influences on urban avian assemblages. Ibis 151:19–39.

Fernández-Canero R, Gonazlez-Redondo P (2010). Green roofs as a habitat for birds: a review. J Anim Vet Adv 9:2041–2052.

Freeman, M. T., Oliver P. I., and van Aarde, R. J., (2018). "Matrix transformation alters species-area relationships

Grant, G., (2006). Extensive green roofs in London. Urban Habitats. 4.

Hanski, I., J. Alho, and Moilanen. (2000). “Estimating the parameters of survival and migration of individuals in metapopulations.” Ecology 81 (1): 239. 10.2307/177147.

Hilty, J., Keeley, A., Lidicker Jr., W., & Merenlender, A. (2019). Corridor Ecology (2nd ed.) Washington D.C.: Island Press.

Holling C. and Gunderson L., (2002) “Resilience and Adaptive Cycles. Panarchy: Understanding Transformations in Human and Natural Systems,” L. Gunderson and C. Holling, New York, Island Books.

HydroTech (2022). HydroTech A Sicka Company. Chicago, IL. https://www.hydrotechusa.com/assemblies/amenity-deck/wood-tiles

Johnston, J., and Newton, J. (1993) Building Green: A guide to using plants on roofs, walls and pavements. London Ecology Unit

Kohler, M., (2006). Long-Term Vegetation Research on Two Extensive Green Roofs in Berlin. Germany. University of Applied Sciences Neubrandenburg, Germany.

Kirby, J. S., Stattersfield, A. J., Butchart, S. H. M., Evans, M. I., Grimmett, R. F. A., Jones, V. R., O’Sullivan, J., Tucker, G. M. and Newton, I. (2008) Key conservation issues for migratory land- and waterbird species on the world’s major flyways. Bird Conserv. Int. 18: S49–S73.

Luckett, K. (2009). Green Roof Construction and Maintenance. New York: McGraw-Hill books

LightsOutGeorgia (2022). Georgia Audubon. Atlanta, GA. https://www.georgiaaudubon.org/lights-out-georgia.html

MacIvor JS, Lundholm J., (2011). Insect species composition and diversity on intensive green roofs and adjacent level-ground habitats. Urban Ecosystems 14:225–240.

Marzluff, J., (1997). Effects of Urbanization and Recreation on Songbirds. Research Gate. Retrieved from https://www.researchgate.net/publication/255594171_ Effects_of_Urbanization_and_Recreation_on_Songbirds

Matthews, S. N. (2008). Stopover habitat utilization by migratory landbirds within urbanizing landscapes of central ohio (Order No. 3312989). Available from ProQuest Dissertations & Theses Global. (193678194). Retrieved from http://libproxy.clemson.edu/login?url=https://www-proquest-com.libproxy.clemson.edu/dissertations-theses/stopover-habitat-utilization-migratory-landbirds/docview/193678194/se-2?accountid=6167

McLain, R.J., Hurley, P.T., Emery, M.R., and Poe, M.R., (2014). ‘Gathering “wild” food in the city; rethinking the role of foraging in urban ecosystem planning and management.’ Local Environment, 19: 220-40.

Morelli F., and Moller A., Tryjanowski, P., (2020). Urban birds: Urban avoiders, urban adapters and urban exploiters. The Routledge Handbook of Urban Ecology, 399-411. https://www.researchgate.net/publication/345319857_Urban_birds_Urban_avoiders_urban_adapters_and_urban_exploiters

Newton, I. (2008) The migration ecology of birds. Academic Press.

Nowak, M., (2004). Urban agriculture on the rooftap. Senior Honors Thesis, Cornell University, Ithaca, New York. USA.

Partridge, DR., Clark, JA., (2018), Urban green roofs provide habitat for migrating and breeding birds and their arthropod prey. PLoS ONE 13(8). E0202298.

Partridge, Dustin R.; Clark, J. Alan (2019), Data from: Urban green roofs provide habitat for migrating and breeding birds and their arthropod prey, Dryad, Dataset, https://doi.org/10.5061/dryad.41s0q7t

Peng, L. L. H., & Jim, C. Y. (2013). Green-roof effects on neighborhood microclimate and human thermal sensation. Energies, 6(2), 598-618. doi: 10.3390/en6020598

Pledge, E. (2005). Green Roofs: Ecological Design and Construction. Schiffer Publishing, Atglen, Pennsylvania, USA.

Roberts, A.J. (2020). Atlantic Flyway harvest and population survey data book. U.S. Fish and Wildlife Service, Laurel, MD.

Rosensweig et al., (2002), Mitigating New York City's Heat Island with Urban Forestry, Living Roofs, and Light Surfaces, New York, NY.

Schmiegelow, F. K. A., and Monkkonen M., (2002). "Habitat loss and fragmentation in dynamic landscapes: Avian perspectives from the boreal forest." Ecological Applications.

Sorenson, A., Greene, R., and Russ, K., (1997). American Farmland Trust, Farming on the Edge, Washington, D.C., Table 7.

Sutton et al. (2012). Prairie-Based Green Roofs: Literature, Templates, and Analogs. University of Nebraska-Lincoln Research Council. https://agronomy.unl.edu/documents/JGB_V7N1_b04_sutton.pdf

Tietze, T., (2018). Bird Species: How they arise, modify and vanish, 235-246. Switzerland: Springer Nature Switzerland AG.

Tryjanowski, P., Sparks, T. H., Kuźniak, S., Czechowski, P., & Jerzak, L. (2013). Bird migration advances more strongly in urban environments. PloS One, 8(5), 1. doi: http://dx.doi.org.libproxy.clemson.edu/10.1371/journal.pone.0063482

UKEssays. (November 2018). Effects Of Urbanization on Animals And Birds Environmental Sciences Essay. Retrieved from https://www.ukessays.com/essays/environmental-sciences/effects-of-urbanisation-on-animals-and-birds-environmental-sciences-essay.php?vref=1

UNC Institute for the Environment, The University of North Carolina at Chapel Hill, P. (2009). Climate change committee report 2009, Retrieved from <http://www.ie.unc.edu/PDF/Climate_ Change_Report.pdf>

UN Data. (2021). First global study shows uneven urbanization among large cities in the last two decades. https://www.eurekalert.org/news-releases/589417#:~:text=The%20world%20has%20experienced%20dramatic%20urbanization%20in%20recent,the%20population%20living%20in%20urban%20areas.%20%28Note%201%29

U.S. Fish and Wildlife Service. (2021) Flyways. Fish and Wildlife Service. https://www.fws.gov/birds/management/flyways.php

Wang, H. (2021). From the flyway to urban landings (Order No. 28546714). Available from ProQuest Dissertations & Theses Global. (2563494651). Retrieved from http://libproxy.clemson.edu/login?url=https://www-proquest-com.libproxy.clemson.edu/dissertations-theses/flyway-urban-landings/docview/2563494651/se-2?accountid=6167

Washburn, B.E., Swearingin, R.M., Pullins, C.K. et al. (2016). Composition and Diversity of Avian Communities Using a New Urban Habitat: Green Roofs. Environmental Management 57, 1230–1239. https://doi.org/10.1007/s00267-016-0687-1

Zhenhuan, L., Qiandu, H., & Tang, G. (2021). Identification of urban flight corridors for migratory birds in the coastal regions of shenzhen city based on three-dimensional landscapes. Landscape Ecology, 36(7), 2043-2057. doi:http://dx.doi.org.libproxy.clemson.edu/10.1007/s10980-020-01032-6