North Dakota State University
Graduate School

Title

CIRCULUS AQUATILIS: DESIGNING AIR CIRCULATION FOR A BETTER SWIMMING EXPERIENCE

By

Jakob Craven

The Supervisory Committee certifies that this ***thesis*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF ARCHITECTURE

SUPERVISORY COMMITTEE:

Dr. Stephen A. Wischer — DocuSigned by: Stephen Wischer CBA6CA6223024AC...
Thesis Coordinator

Dr. Ganapathy Mahalingam — DocuSigned by: Ganapathy Mahalingam CCDF0AA3BE08476...
Primary Advisor

Approved:

05/10/2024 — DocuSigned by: Susan Schaefer Kliman C9FF1C4ACFB7438...

Date — Department Chair

CIRCULUS AQUATILIS: DESIGNING AIR CIRCULATION FOR A BETTER SWIMMING EXPERIENCE

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Jakob Craven

In Partial Fulfillment of the Requirements
for the Degree of
Master of Architecture

Major Department: School of Design Art and Architecture

May 2024

Fargo, North Dakota

ABSTRACT

Air circulation in natatoriums is a very crucial part of pool design. Improper design of the HVAC system can lead to respiratory problems for swimmers, lifeguards, or even spectators. Having experienced multiple pools with this issue before has led me to push to investigate this problem further.

The focus of my research is to get a better understanding of how air circulation works within a natatorium. This will primarily look at the design elements of natatoriums such as air changes per hour, flow rate, and proper placement of vents for supply and return and see how each function and influences one another during the design process. Secondly testing the air flow of this space will check to see how successful this design can function as a natatorium when in use.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASHRAE..American Society of Heating, Refrigeration and Air-Conditioning Engineers

CFD..Computation Fluid Dynamics

HVAC ....Heating, Ventilation, Air Conditioning

IAQ ....Indoor Air Quality

LIST OF APPENDIX FIGURES

1. INTRODUCTION

1.1.1. Research Question

How to design an effective HVAC system for an aquatic facility to keep the air quality at a comfortable level for those always using the facility?

1.1.2. Proposed Outcomes

This project plans to have three to four variations of digitally modeled HVAC systems. Each model will progressively get more detailed trying to improve upon the previous iterations. By exploring different orientations and placements of model objects we will be able to see which models are more efficient compared to each other.

The impact of this research might have on this typology will bring notice to how we design for air quality and comfort in natatoriums and similar aquatic buildings. This should also give a better understanding of how we adapt these buildings in areas that have drastic weather changes throughout different parts of the year.

1.2. Objective

Recently Grands Forks's swimming programs have been fighting an up-hill battle to stay active. There are multiple factors that have been the cause of this, but the biggest issue has been that the city's indoor pools have been shutting down. This is due to the age of the buildings, not enough funding, or the design of the pool causing problems. Currently there is only one competition pool in Grand Forks open which is the Hyslop found on UND's campus. This pool is planned to be shut down in the to be turned into a STEM lab for the university. Once this happens there is a chance that all swimming programs will be discontinued until the city builds a new pool.

Figure 1: Central High School

Figure 2: UND Hyslop

1.2.1. Aim

The air quality in an aquatic facility should be the number one priority when it comes to designing a facility like this. The aim of this research is to investigate how we can design a natatorium that efficiently circulates the air to keep the air quality and temperature at a comfortable level for the spectators, the athletes that are competing and the coaches standing on the pool deck.

1.2.2. Significance

Focusing on the air movement in any building is vital so it doesn't become stagnant, helping prevent the development of respiratory issues for those who use the space. This is a major component when it comes to designing any kind of typology that needs a heavy-duty HVAC system. The significance of this research will be to help design a system that keeps air moving and fresh while circulating and filtering chlorine particles out. This will provide the comfort needed to stay in an aquatic center for long periods, lowering the risk of respiratory issues for the users over time.

2. Background

2.1. Background

A few of the major issues that are common of long-lasting indoor pools is the age of the equipment to support the pool and how it has been maintained. These two factors affect how well the air quality is in the building and how well it is circulated. This can be caused by the equipment not being properly calibrated for the activities that happen during the day, weather conditions throughout the year, or the systems aren't routinely checked for maintenance. In conjunction with this is the deterioration of the walls. As a natatorium ages the buildup of moisture within the walls is bound to happen. This causes molding, and crumbling of inside components which can be very expensive to repair if not designed properly. Designing to prevent these issues from the beginning will slow down the process of facility failure by a considerable amount.

2.2. Literature Review

2.2.1. Air Quality

USA Swimming has done extensive research already discussing the air quality of pools. A major factor they explain are differences between the use of chlorine and chloramine. Chloramine is a chlorine and ammonia compound that is more stable than chlorine. Chloramine, unlike chlorine, dissolves at a slower rate which leads to less eye, skin, and cardiovascular damage overtime in swimmers and lifeguards (*USA-Swimming-THE-AIR-QUALITY-ISSUE.Pdf*, n.d.). This will be very useful for deciding on which system to use in my design concepts as they both affect the pool systems' wear and tear differently.

It also goes in depth on the proper use of UV light to help with the water treatment of the pool. The use of UV in a pool is highly lethal to viruses, bacteria and mold (*USA-Swimming-THE-AIR-QUALITY-ISSUE.Pdf*, n.d.). Using UV light also helps reduce the use of chlorine which in turn keeps a pool much cleaner in the long run. This also reduces the amount of chemicals needed to keep the water clean which can affect companies that sell the chemicals to the pools.

A big part of this research is going to be looking at the ventilation systems that will be used within the pool. This system brings in fresh air while pushing the heavier chlorinated air out. This will be the hardest part to design when it comes to managing the chloramine and humidity levels. Looking at keeping the exhausts lower to the ground will make managing these elements easier than having them too high (Consulting, n.d.). There will still be a need for higher ventilation as hot air still rises making the room humid and will need a way out. Another reason why there should be lower exhausts is because the chloramine particles are heavier than oxygen. These particles settle more on the surface of the water and pool deck area which can cause many problems to the body if not circulated correctly. Making sure these systems work together at the correct ventilations speeds will produce great air quality with very little discomfort.

Air conditioners are great for what they do, but they are not designed for anywhere near the demands of an indoor swimming pool (Consulting, n.d.). Knowing this, making sure the right size dehumidifier will be essential for keeping the humidification levels low. There will still be the use of an air conditioner, but this will be more applied for the stands and for the lobbies or other rooms/offices. Pool dehumidifiers, on the other hand, optimize energy recovery, using features like pre-heat and/or reheat coils (Consulting, n.d.). This is important because this could lead to looking at some ways to make the ventilation system of the pool as energy efficient as possible. Pursuing this will lead to lower energy bills and if the building systems are designed properly will also make maintaining the equipment much easier.

2.2.2. Respiratory Issues

Respiratory issues are not uncommon when it comes to athletes in swimming. Some of these are preexisting conditions for the athletes. Others, if not born with respiratory issues, can develop these conditions through their career with the sport. While exposure to chlorinated air is a factor to cause respiratory issues The International Olympic Committee recognizes that endurance training itself is capable of increasing the risk of airway disfunction (Lomax, 2016). So, while the air quality in an indoor pool needs to be a top priority the individual use of the building will lead to varying development of airway dysfunction among athletes. The two biggest causes of airway disfunction is that swimming forces you in a horizontal position and that the breathing frequency is lower in general.

Swimming is unique in that unlike most sports where the athlete is typically in a vertical position swimming in a competitive environment happens in a horizontal position. This positioning because of added pressure from the water makes it difficult for the chest to properly expand while taking a breath. Nonetheless, trained swimmers have a higher forced vital capacity, forced expired volume in the first second of exhalation, total lung capacity, vital capacity, inspiratory capacity, and pulmonary diffusion capacity and chest surface area compared with runners (Lomax, 2016). This means that with proper conditioning a swimmer can go longer distances while taking fewer breaths as a result.

Making sure the air is as fresh as possible will help swimmers maintain their breath control as they swim during practices and swim meets. Violent coughing on a pool deck comes from there being too much chorine in the air. This can be the start of asthma development which can cause more serious sickness development if not handled or treated properly. Prioritizing athletes' health is one of the top goals for any athletic facility. If that is not taken care of first, then the building has failed before the first practice has even started.

2.2.3. Pool Design

The design of the pool in a natatorium dictates whether it will be successful or not. Using Natatorium Design Guide by Ralph Kittler and A Guide to an Integrated HVAC System Design Guide provided by Desert Aire will be integral for designing how a pool will function for different events. Starting with basic elements for a pool used for competition and recreation the air temperature should be set from 75 to 85 degrees Fahrenheit. This gives the facility a range to keep the environment at a controlled temperature if the there is a swim meet happening or if there will only be recreational use for the day (*Natatorium Design Guide*, n.d.). For indoor air quality (IAQ) to stay at a comfortable level there needs to be a certain amount of air changes per hour. Recommended by AHSRAE for a pool with spectator seating there needs to be about 6-8 air changes per hour. This prevents the air from becoming stagnant and possibly causing sickness for the users. The walls for a pool need to be designed carefully as well. Natatoriums are very humid in general, and moisture can get into the walls causing damage over time. To help mitigate this damage there needs to be a vapor retarder set on the warmest side of the wall. With the vapor retarder and supply air working together this will reduce the condensation and moisture that typically forms during the day. Another thing to keep in mind is that there can be no vapor retarder set on both sides of the wall. This will for sure trap any moisture that may find its way in and have nowhere to escape also causing damage.

For the layout of the supply air circulating the pool, the duct work should be in the shape of a "U". This hits three sides of the pool providing the walls and windows with dry air lowering the rate of condensation buildup while in use (*Brochure-21st-Century-Pool-Design-Guide-DA030.Pdf*, n.d.). For the air to be properly filtered out there needs to be a high, medium, and low air return system. A natatorium can be a relatively warm area so as the cool air circulates the pool will eventually begin to rise. The high and medium returns will primarily focus on circulating the air provided by the supply. The high returns need to be set as close to the ceiling as possible and the medium returns placed up typically 6 to 8 feet. This prevents most furniture from blocking them and allows for air to freely flow. These returns will then send the chlorinated air to a dehumidifier filtering out the chemicals and releasing it back to the outdoor air. The low return, also called an evacuator, is used to also filter the air but will have a higher number of particles to handle as chlorine particles tend to stay low. This will be separate from the other returns and releasing filtered air to the outdoors as well (*Brochure-21st-Century-Pool-Design-Guide-DA030.Pdf*, n.d.).

2.2.4. Gap Identification

There are two areas that will need to be focused on for the design of this natatorium, first will be the main air circulation system. Using both design guides will make sure that elements of the system are effective and efficient when in use. The main supply air will need enough air flow to circulate the chlorinated air properly and evenly to the return ducts. If the flow is not set high enough, then there is the possibility of air becoming stagnant as stated before. Studying and understanding how the HVAC system ducts are layout will greatly prove how successful this project will turn out.

The pool deck will also be a major priority because this is where most of the chlorine/chloramine particles settle. This is also where the skin, eye, and respiratory issues are most common. The testing and designing of different exhausts and duct configurations will give great insight as to where elements of each test fail and succeed. Focusing on how each exhaust gets to the returns will also show how efficient the iteration is at circulating the air properly overall.

2.3. Project Type

The focus of this thesis is to provide a natatorium for the city of Grand Forks with a major focus on the air circulation for the facility. The sport of swimming is not as talked about compared to hockey, baseball, or football but is just as important to those who are involved in it. Providing a new facility for the city near other similar amenities should help bring in new interested individuals mainly kids who might want to join any of the swim team programs already established. Using the Hulbert Aquatic Center set in West Fargo, North Dakota as a guide for this project should help in developing the final solution of this project. This building was chosen because it is the newest aquatic center in North Dakota currently. It was the Olympic trials pool for the 2016 Olympics in Nebraska and was donated to West Fargo by UP Aquatics. The facility has all the necessary elements to properly handle the heating, air circulation and pool filtration to ensure that the users of the facility are always comfortable. The problems this pool has had in the past were handled within the first two years of its operation. The air circulation system failed during a swim meet in 2019 causing multiple users of the facility to become sick from the poor air quality. This was quickly fixed a few months later and now has a fully functioning air circulation system and is considered one of the best competition pools in the area. This will be used as the base line of the project focusing on the air circulation and proving a clear understanding of how this system works to filter chlorinated air and release it back out as fresh air.

3. METHODOLOGY

3.1. Approach

During the first month of this research, most of the time was spent figuring out how to use Autodesk CFD (Computation Fluid Dynamics). The initial plan was to build three different models in Revit and put those models into the CFD program. This process at the start did not work in my favor for multiple reasons. The biggest issue I believe is that Autodesk CFD (the student version at least) could not handle the scale of the building that I am trying to work with. Other issues stemmed from the HVAC system components Revit provides seemed to be causing problems with making the shell not fully sealed. I also had to take out furnishings like bleachers and diving blocks/ boards to make the model load faster.

Eventually, with the help of my professor we found a solution to the problem. I would use SketchUp to create multiple two-dimensional section cuts of the pool. This method will be much faster to produce test results by quickly adjusting elements of the test model seeing what placements worked for the model and would allow me to easily understand how the building would function and discover where issues may occur in the system.

My new approach for my project is to create section cuts in SketchUp of one pool as a dependent variable. I will then design an HVAC system layout for each variant which will be used to test how the air circulation performs within the building. After each test I will modify the HVAC system to see how each of the changes would affect the air flow or to see what changed elements caused issues. This will be done three times with the hope of each iteration improving upon the last.

There will also be three tests done on each iteration to see varying levels of efficiency of the air circulation. I will be adjusting the air flow rate of the main system. Each test will start at 100 ft/s and go down by a factor of 25 ft/s for the next two. This should allow me to see which flow rate would be the most optimal to use.

Lastly there will be an exhaust duct that will be set at no more than 30 ft/s. This will be used to simulate the exhaust that pushes the chlorine particles that would be produced. This is an important element to include because this is the fan that pushes the particles toward the return ducts keeping them from piling up along the water's surface and pool deck. If this was not included particle build up would cause damage to the athlete's respiratory functions over time.

3.1.1. Data Collection

Each variant will be using the same three section cuts for testing. The first test being the length of the pool followed by the width of the pool in the shallow and deep end. The length section of the pool shows where the supply and returns are placed. The supplies will be placed towards the ceiling. This is so fresh air can be taken easily from the roof of the building and sent down to ventilate the space. Spaced out through the main supply duct will be fans. These fans are important for the system because as the air is sent from the supply the air pressure weakens as it travels to the ends of the duct, they will help push the fresh air through the duct and down to the pool.

On the bottom left-hand side of the length section is another supply duct. This is called the exhaust which will be set at 30 ft/s for all tests. The exhaust is not designed to ventilate the entire pool but to help push the chlorine particles towards a return as they settle along the surface of the water and pool deck.

On the right-hand side of the section will be the placement of the return ducts. This is where the air sent from the supply will be filtered from the chlorine particles. As each test is conducted these will change positions and sizing to help better understand where it would be most efficient to have the returns placed. The width tests are laid out almost the same. The two major differences between the length and the width tests are now we can see both supply ducts and the layouts and sizing of the returns.

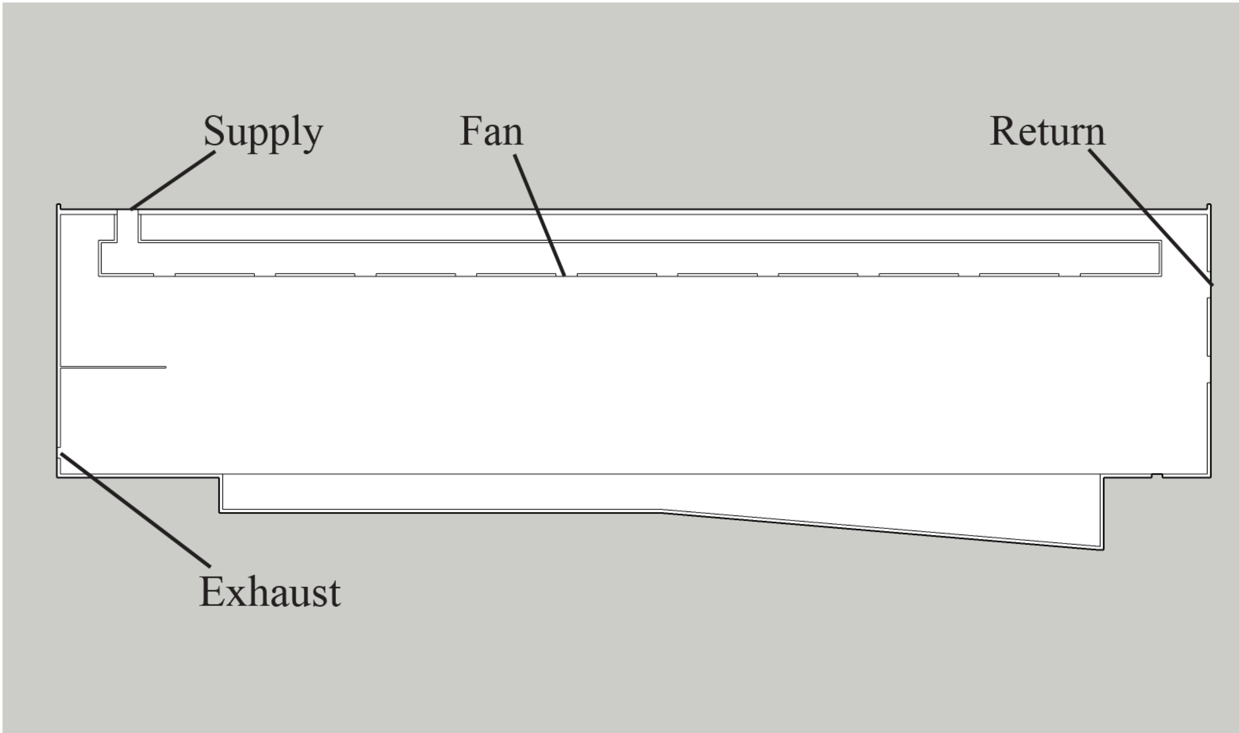


Figure 3: Length of Pool Example

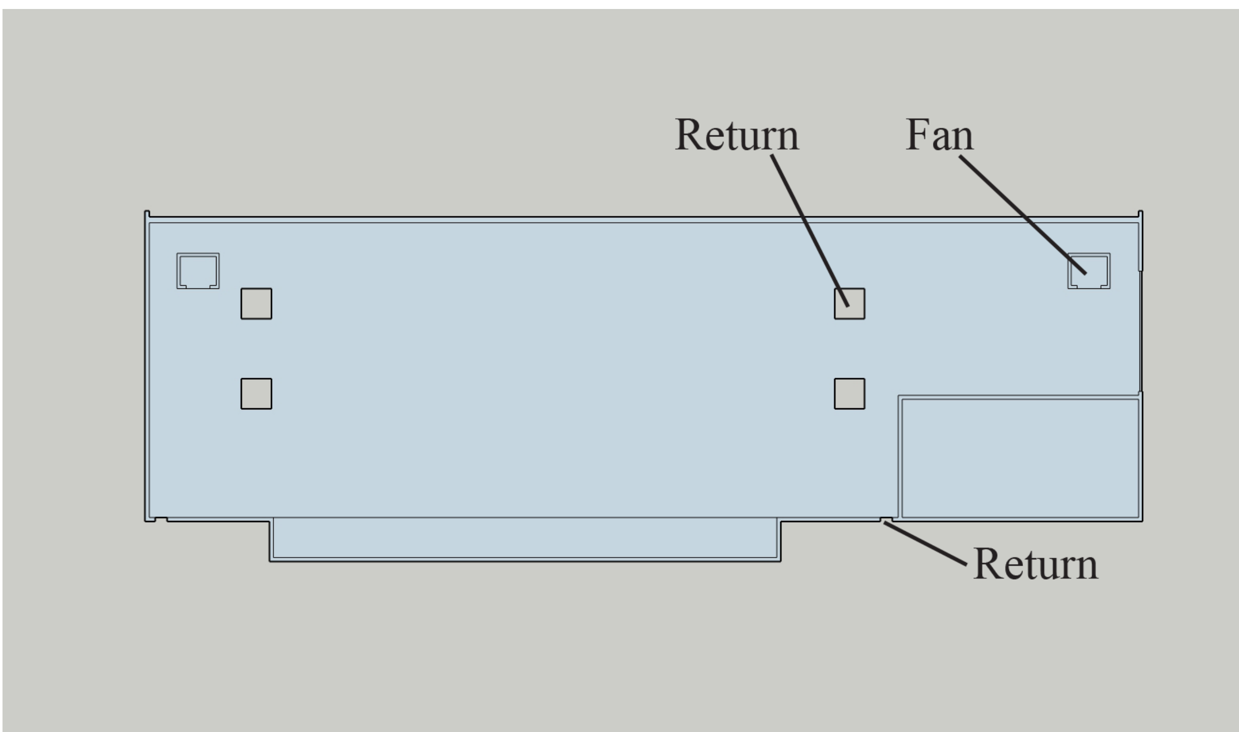


Figure 4: Width of Pool Example

3.1.2. Analysis

The main method for gathering the data I will need for my project will be designing models that will have varying design elements to them ranging from basic shapes to more complex. This method will allow me to analyze where each model can be improved upon. This data will then help me design a new model or improve an old model that was efficient to be used as the main project for my thesis.

The tools I will be using for this analysis will be Revit for designing the different concepts of the building and using the implemented HVAC items to layout the HVAC systems and equipment. I will also be using Autodesk Computational Fluid Dynamics (CFD) to analyze the air flow and temperature of each concept with varying occupancy loads. Lastly, I will use AnyLogic which is a program that will be used to study the effect of humidity off each model.

Using all these tools will help me get a better understanding of how the mechanical systems of a building can affect the way this typology is designed. Another goal is to learn more about how indoor pools manage the different levels of humidity while making sure the equipment is being adjusted properly and not overworked for different events and daily use.

3.1.2.1. Variant 1 Analysis

For variant one I wanted to keep it simple to start with. The idea was to get familiar with the CFD program and figure out the proper settings to use for the rest of the tests. Variant one's supply ducts were kept to a square shape along with the return ducts. This was done to also see how the air would flow with the supply pointing straight down to the floor.

The returns were placed accordingly to allow for plenty of space between them for air to flow and rise freely. The returns in the floor along the side walls are to catch the initial chlorine particles that form and are pushed from the exhaust fan while the pool is currently active. The other two rows of returns are to help catch any particles that were missed.

The end results of each test at the various are speeds showed plenty of air movement. Variant Ones biggest issue was the placement of the Left-hand side return ducts the width sections. Since the supply was aimed directly down to the floor a lot of that supply air went straight to the closest return. While this isn't totally accurate to how this would function it should be noted that even on the right-hand side the air that is supplied almost immediately flows toward a return before hitting the ground.

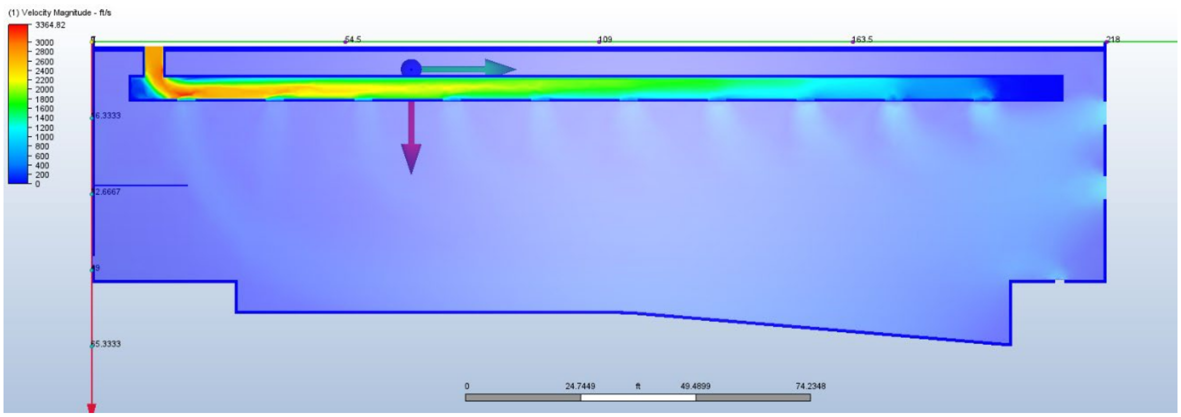


Figure 5: Variant 1 Pool Length

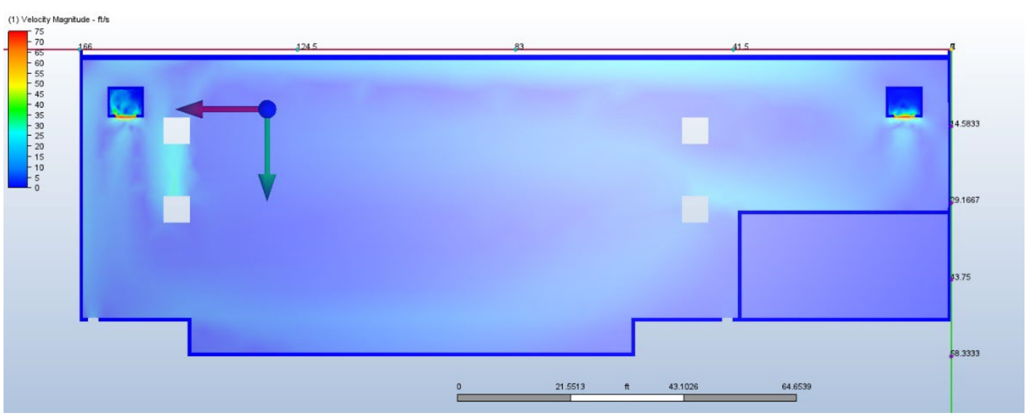


Figure 6: Variant 1 Shallow End

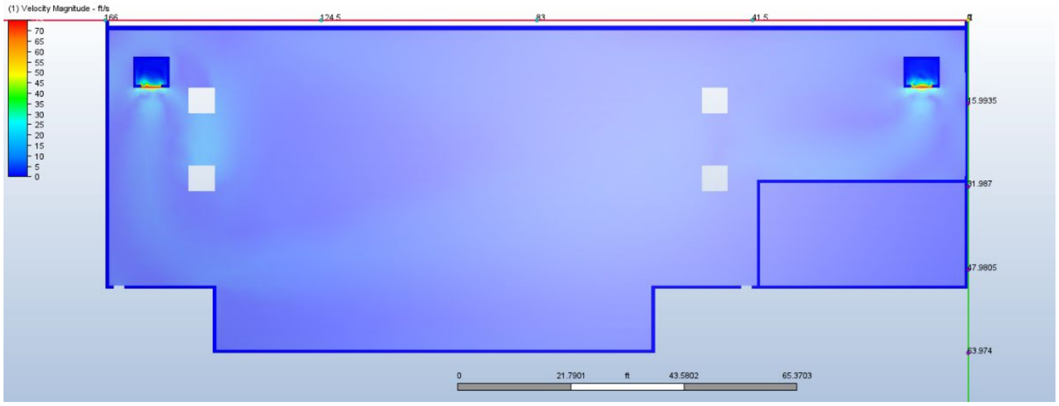


Figure 7: Variant 1 Deep End

3.1.2.2. Variant 2 Analysis

Once Variant One was completed I finally had a good understanding of how the program worked and easily figured out what to improve upon after reading a few documents about natatorium and system design. The most important change I made for Variant Two was making the supply ducts a circular shape. The reason for this change was to keep the buildup of condensation low along the windows and exterior walls, the supply duct fans would have to be aimed towards said elements. Making this change allows the air to be pushed down the wall making it so the air has the proper amount of time circulate before being sent to the returns.

For the returns I added two more returns and made them taller. I also moved the left-hand side returns away from the supply ducts. These changes were done to allow for more air movement to happen while having more access for the old air to return to without having the risk of particle build-up within the pool.

I also had a conversation with a pool consultant to help me decide how I should layout these systems. He told me that the returns that are within the pool deck should be closer to the pool rather than the walls. With them being close to the wall risks them of being covered by towels or swim bags that would be present during a competition causing chlorine particles to not be properly ventilated. Knowing that I moved the floor returns toward the middle of the floor.

The results of this test were much improved over the previous one. The change in return placement and changing the angle of the supply dramatically helped with the air flow seen in the figures. On both sides the air properly slides down the wall and onto the floor which its indented path should have been on the previous test.

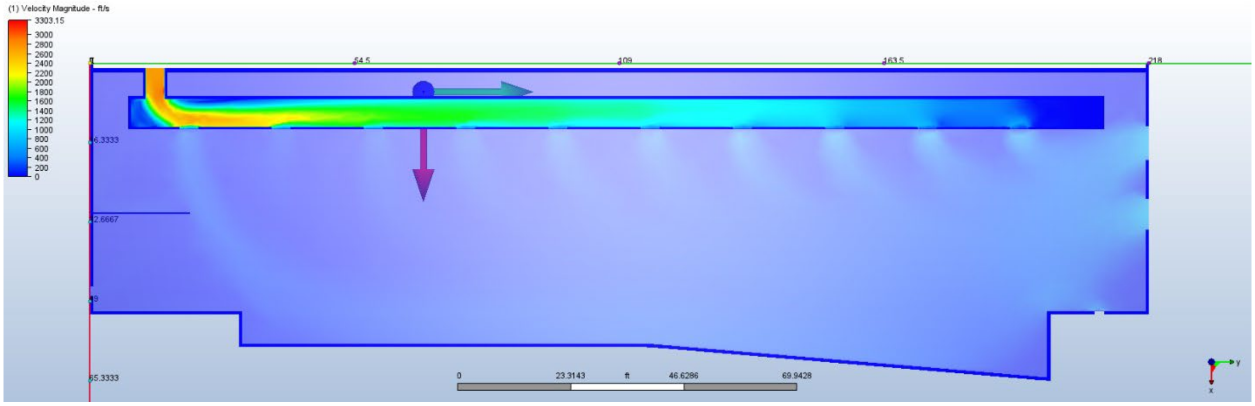


Figure 8: Variant 2 Pool Length

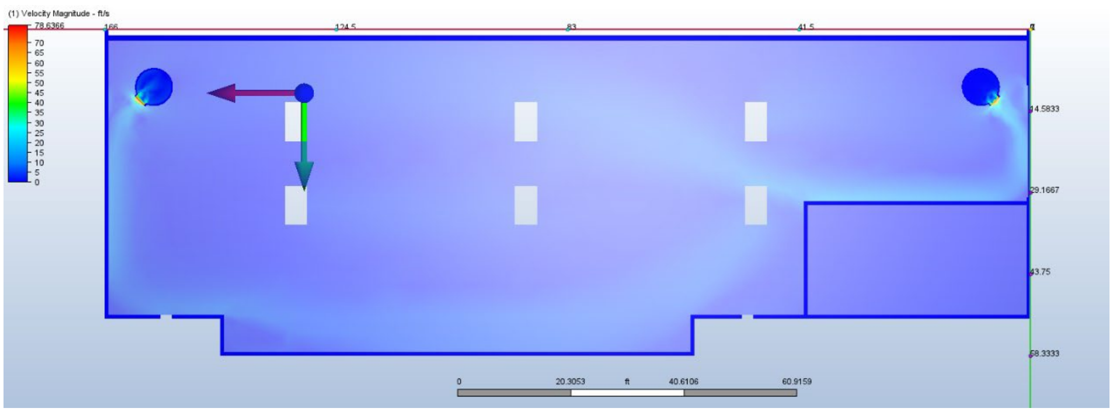


Figure 9: Variant 2 Shallow End

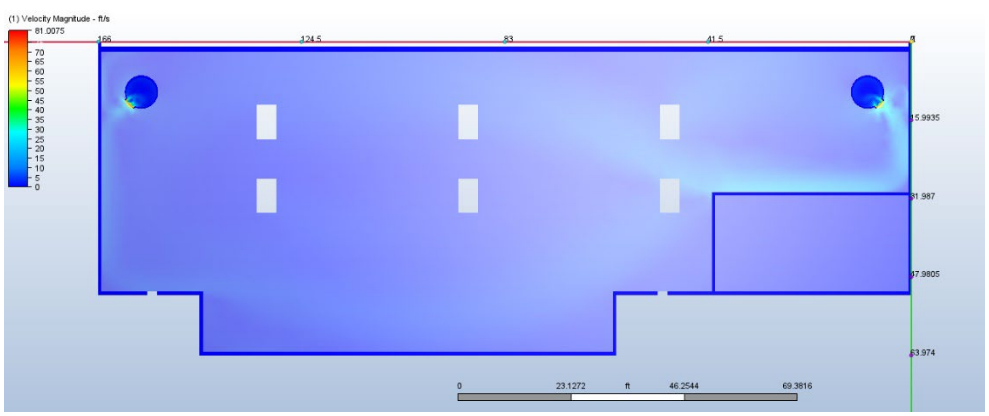


Figure 10: Variant 2 Deep End

3.1.2.3. Variant 3 Analysis

For Variant 3 I kept the new supply ducts and added one smaller duct. This new duct's main function is to cool the spectators that would fill the stands. I got this idea from coaching a meet at The Hulbert Aquatic Center in Fargo. As this was its only function, I could allow it to be smaller and have half the air flow the main supply ducts provided.

After reading more about how the return air should be managed, I learned that the return should be set as close to the ceiling as possible. The reason for this is because as the supply air is sent these are much cooler than the air that's already within the building. As these particles move throughout the room, they will start to warm up causing them to be less dense which then makes them rise towards the ceiling. With that in mind, I removed the second column of returns and raised the top two to be about 4 feet from the ceiling. The reason for removing the two columns was because with these four returns being spaced out along with the ones on the floor there should now be plenty of space between each return to pull in old air as it starts to rise. There was also a new floor return on the right-hand side added to help with more ventilation.

The results for this test I would say are close to the previous one. The newly added supply looks to have helped the right side be fully ventilated. The left side seems to have very little circulation compared to the previous test. I believe I could push the wall returns out to the side a few feet to help with a bit more air movement.

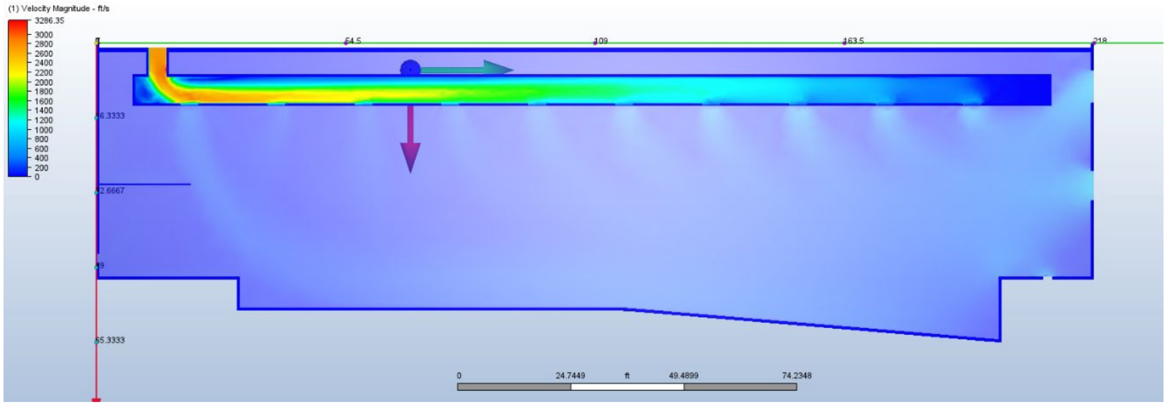


Figure 11: Variant 3 Pool Length

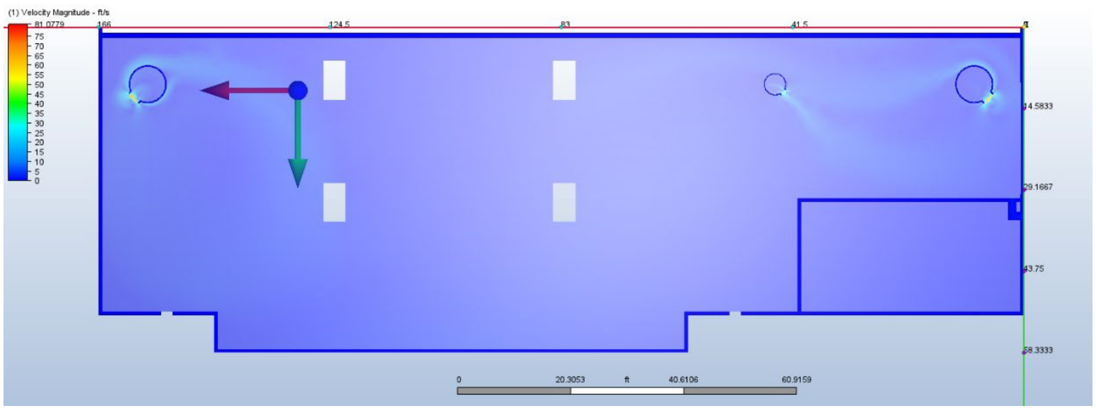


Figure 12: Variant 3 Shallow End

Figure 13: Variant 3 Deep End

3.1.3. Conclusion

To reiterate the goal of this research was to gain a better understanding of how the air circulation system works for a natatorium. This was done with the use of SketchUp to design each of the iterations, and Autodesk CFD to perform the air circulation studies to see what elements work in each iteration and to figure out what can be improved for the final design.

Overall, I believe I have been successful in what I set out to accomplish with this research. I've learned so much through this process on the workflow for a CFD program and experimenting how different air speeds affect such a big space. Finding a balance between using an air speed between 50-75 ft/s will be the most effective to use for this project. This range allows for plenty of air circulation to happen within the space and not causing the pool deck to be too cold for the swimmers to handle. This will be an important factor to consider keeping all users of the space to be in a comfortable state. The exhaust will be set at 30ft/s for the final design. As the pool length is quite long having that air along the surface be quickly filtered will make the building more efficient.

Being limited to only a two-dimensional workflow for my research was a challenge. Since it is only a flat space, I had to think of some work arounds when laying out the systems. While this was still effective and led to more creative thinking, as a result it would be more ideal to be working with a more three-dimensional model instead. This workflow has allowed me to have a much better understanding of how a natatorium is designed and how precise each of the systems needs to be to function properly than I previously had. I will continue to use Autodesk CFD to develop a final design for next semester that will be a more detailed and refined model compared to these previous tests.

The importance of this research is to bring to light how much a natatorium relies on the HVAC system. This system needs to be designed sufficiently for the specific natatorium so the systems can circulate the air to prevent stagnant air from forming, condensation build up on the walls, and most importantly the filtration of the chlorine particles in the air.

3.2. Project Location (Large Scale)

The city this thesis project will take place in is Grand Forks, North Dakota. This project will be in the southern part of the city near the Choice Health and Fitness Center off South Washington Street. The population of the city is 58,460 people with most of the population living in a suburban setting. The climate of the city comprises of dry and humid summers that last from June to mid-September with a shorter fall and spring season from April to May and mid-September to November respectively. The rest of the year is left for the long and cold winter season.

Figure 14: Overall City Map

3.3. Project Location (Small Scale)

The surroundings of the site are part of the growing development that is taking place in the southern part of the city. Around the area are a few neighborhoods with some schools relatively nearby. There is an Altru clinic to the west of the site and a fire station to the south along with various other businesses populating the area.

The biggest reason for choosing this site is because of the nearby fitness center and hockey arena. This is a great location because of all the activities that are in this area for children to grow, make friends and stay healthy. The addition of the pool here will only help encourage more people to come to this area and make new connections with others.

Figure 15: Neighborhood Map

3.4. Specific Site

The site itself is located at 4301 S Washington St. which is a vacant lot west from Choice Health and Fitness. The lot is part of zoning code C which is for commercial use. The area of the lot is about 161,710 sqft which will be big enough to house the new pool while providing room for adequate parking. The important nearby amenities are the Choice Health and Fitness Center and the Icon Hockey Arena and the Altru clinic. The fitness center already has a swimming lesson program in use and being able to transfer that program to the new pool would help greatly in bringing in the revenue needed to run the building. The other major amenities surrounding the area are heavily used for most of the year and will assist in encouraging people to visit the site.

Figure 16: Site Map

Figure 17: Site View Looking West

Figure 18: Site View Looking North

Figure 19: Site View Looking East

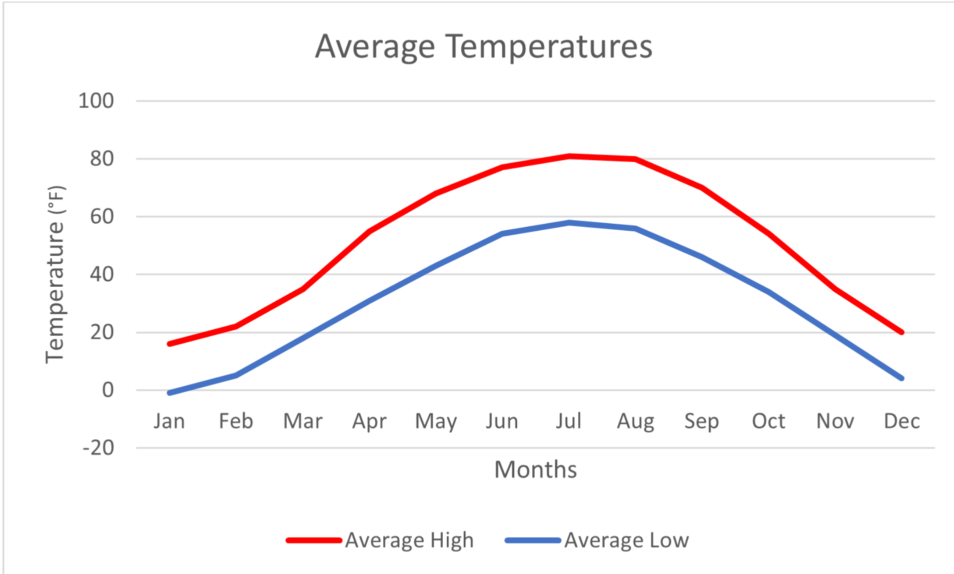


Figure 20: Average Temperatures

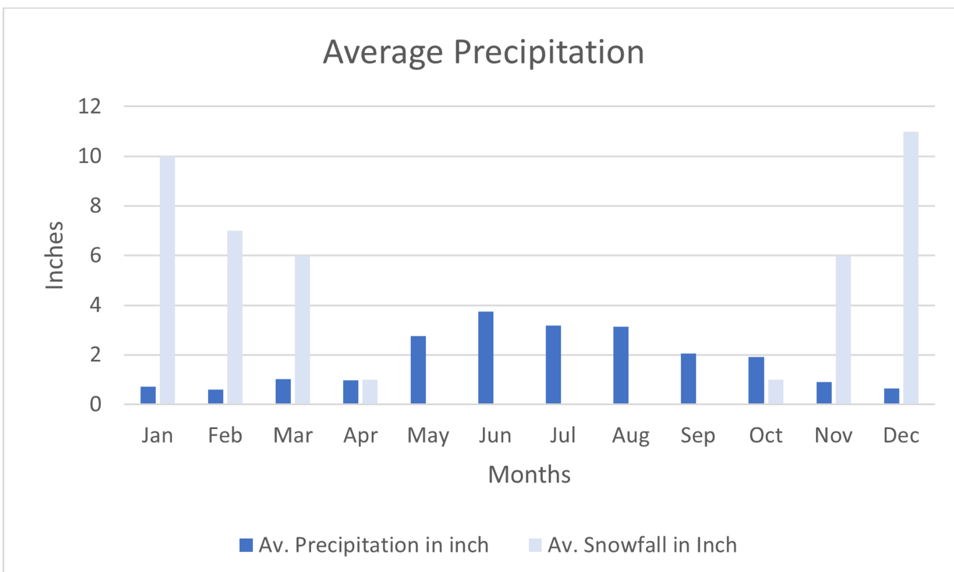


Figure 21: Average Precipitation

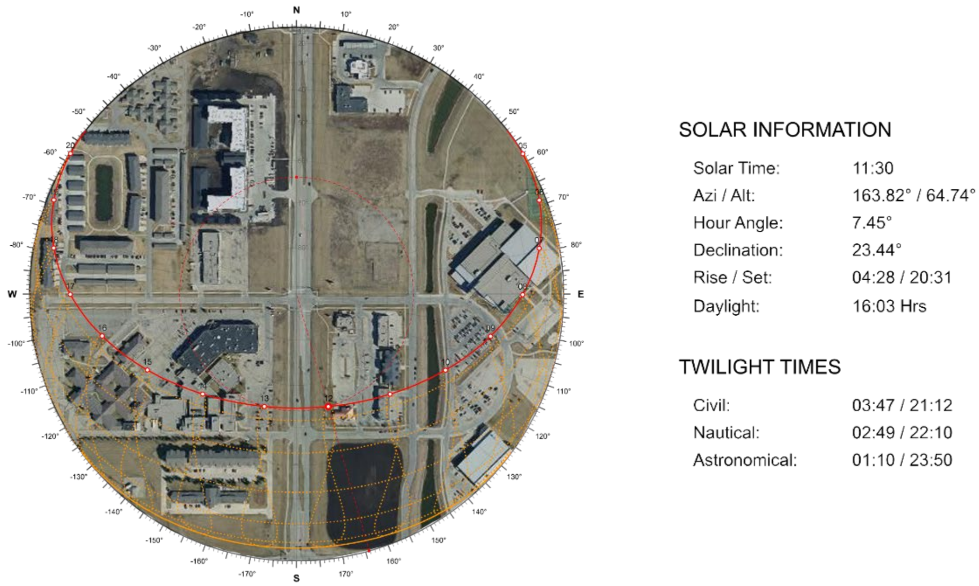


Figure 22: Summer Solstice

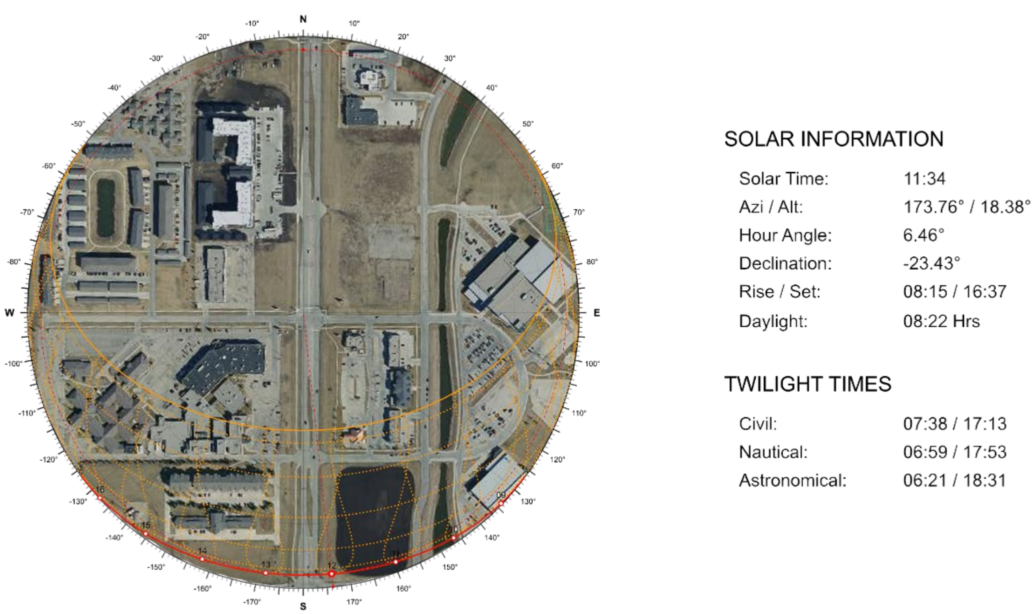


Figure 23: Winter Solstice

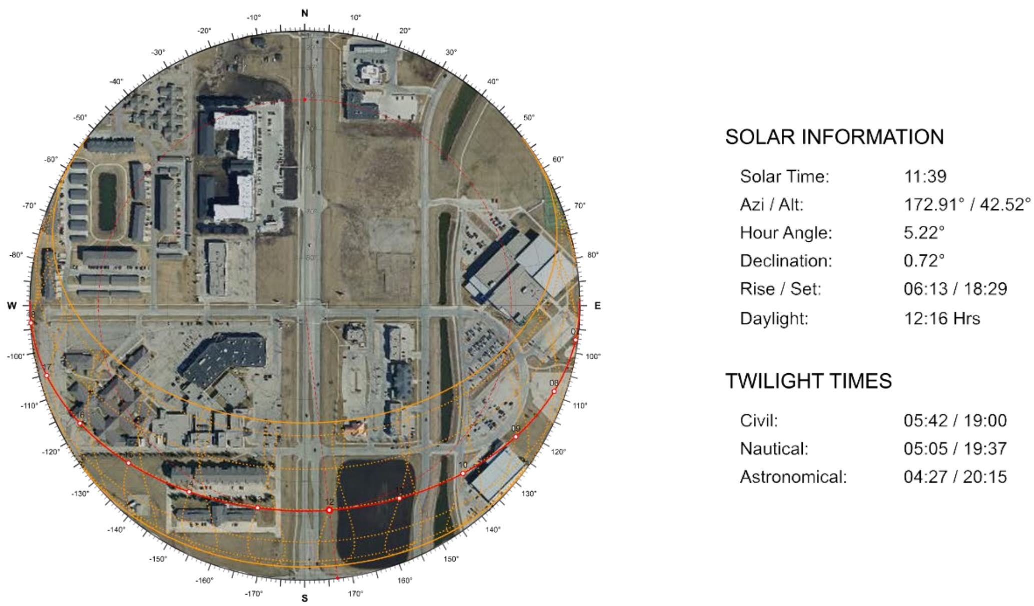


Figure 24: Fall Equinox

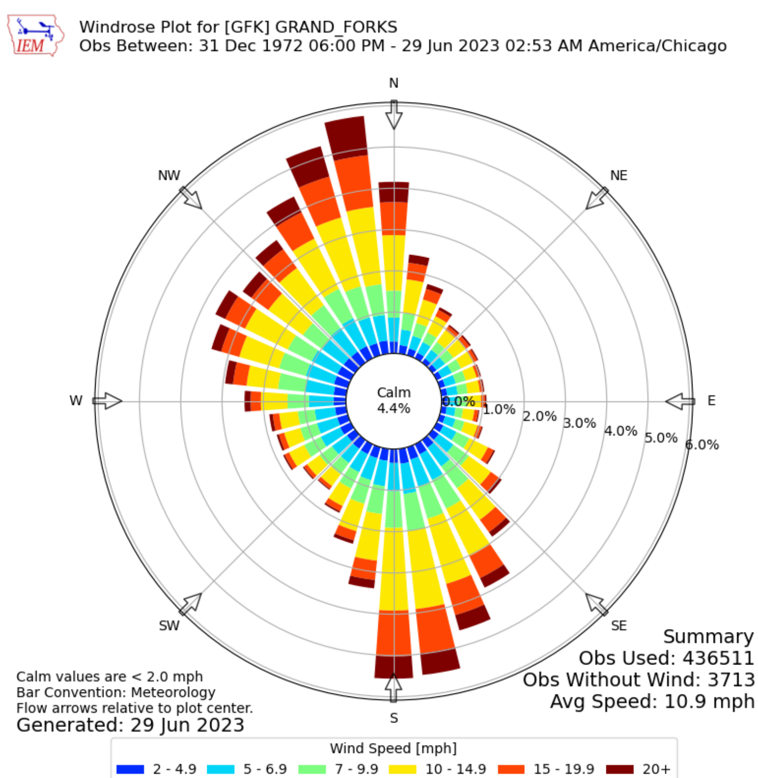


Figure 25: Windrose Plot

3.5. Precedents

3.5.1. Hulbert Aquatic Center

The Hulbert Aquatic Center is located in West Fargo, North Dakota and built by Zerr Berg Architects. It was originally an indoor pool opened in 1976 and ran by West Fargo Public Schools District for over 40 years. In 2015 a school district bond containing an $18.3 million dollar package for a new aquatic center was passed. Using the 2016 Olympic Trials pool in Omaha, Nebraska as the base design it was purchased and upgraded with a $3.2 million dollar donation by UP Aquatics. The aquatic center is 54 meters long by 25 yards wide allowing for accommodations of short course and long course seasons that take place during the year. The aquatic center opened in spring of 2018 and is now the home of many high school and club teams for the city.

This building was chosen as a base for the structural system to understand where loads should be transferred to and to gain inspiration on the layout of the HVAC system. As it was designed based on the Olympic Trials pool it has a state-of the art air circulation system providing fresh air to the building. Studying how this building operates will make designing this project much easier to do while gaining a greater understanding of properly sizing structural and HVAC elements not previously knowledgeable on.

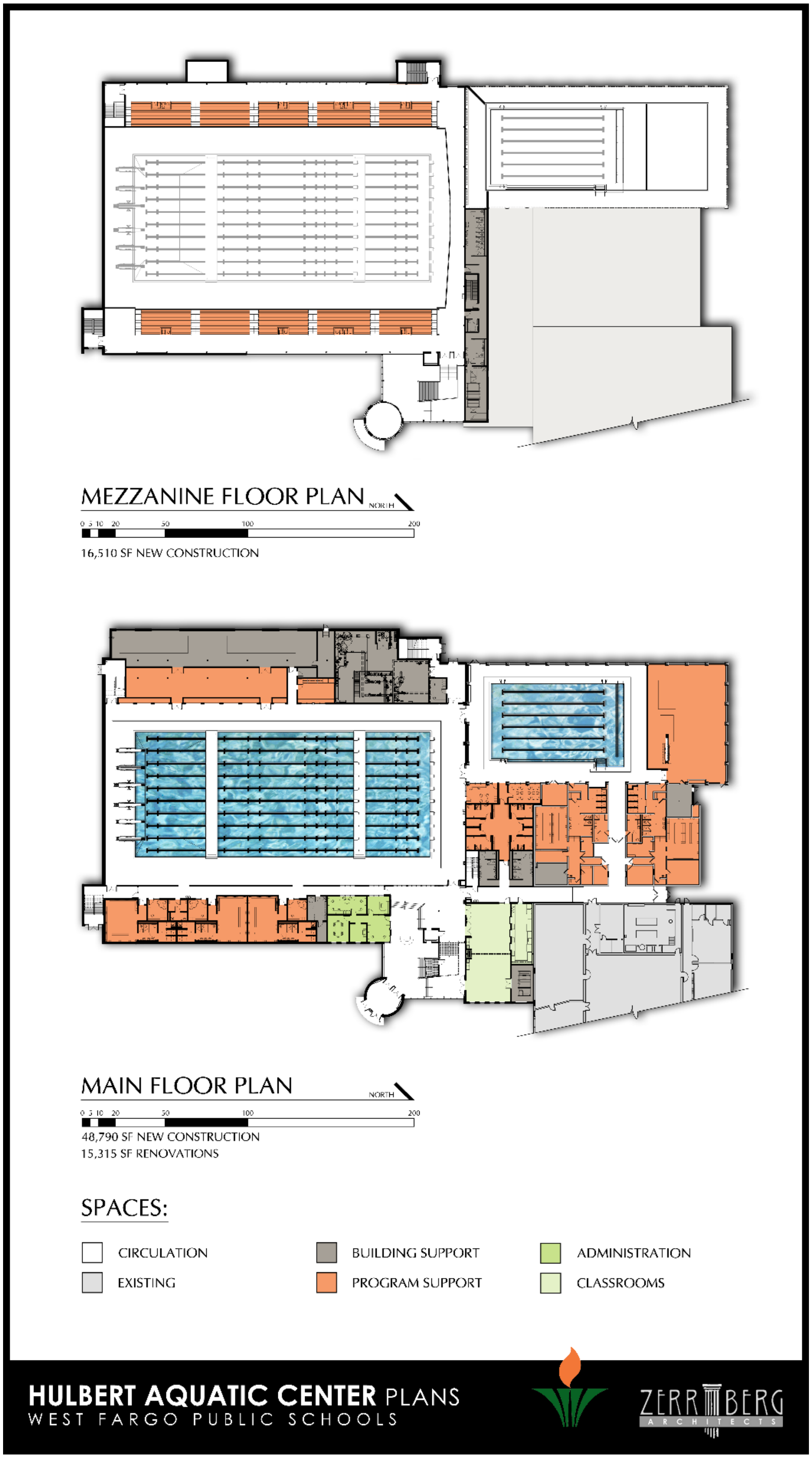


Figure 26: Hulbert Aquatic Center Floor Plans

Figure 27: Hulbert Aquatic Center Competition Pool

Figure 28: Hulbert Aquatic Center Lobby

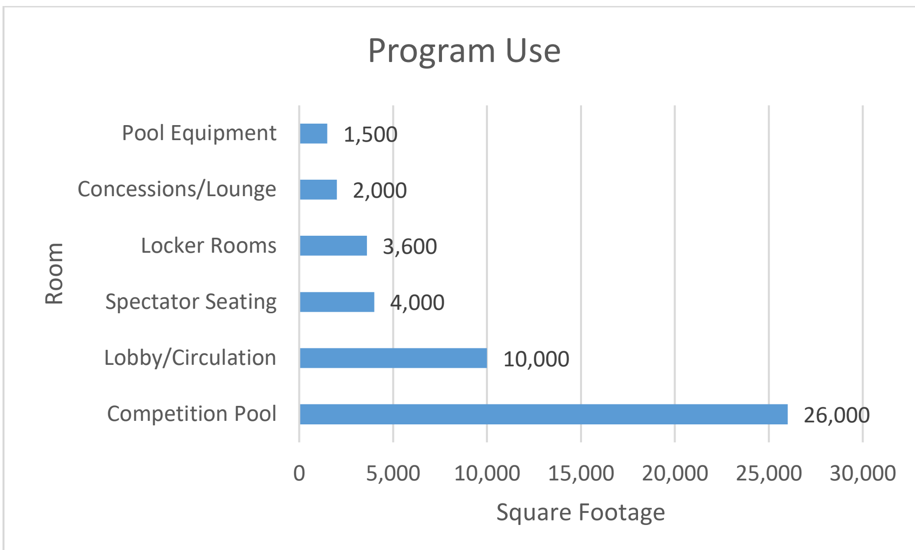
3.6. Space Program

For the program use of the pool each component is important to making sure the building does not need any additional addons in the future. The lobby and circulation will be the biggest factors when designing the layout of the building. The lobby needs to be big enough to hold multiple people without it feeling claustrophobic. For the circulation this will determine the layout of the building. Making sure this is easy to navigate for all users will make the building a very pleasant experience. The next important part would be the spectator seating. The pool should have enough seating to fit at least 1,000 spectators at any time any less than that would cause friends and families to be too close together. This would make people understandably uncomfortable and would increase the body temperature of everyone rise being so close adding to the already warm environment.

There should be at least one family locker room and four larger locker rooms. Locker rooms will need to be sized properly to be able to store all the athletes' belongings during any size of swim meet. The pool storage should be big enough to store all lane rope reels. These take up the most amount of space and will need two sets, one for the short course season and a set for the long course season. This will also hold the general pool equipment that will be used. The mechanical and electrical room will be combined for easy access on the pool deck. Here is where the pool filtration system will be installed as well as some of the air circulation system.

The faculty will have a few coaches' offices, a pool manager office and lifeguard office. These three will be next to each other for quick access for any emergencies that may arise during practices or other events. Next there will be an administrative office, this will be where non-lifeguarding staff will be working. This will be responsible for registration of classes or job employment and the regular day-to-day activities that will need to happen.

Last is the competition pool, which will be a 50-meter Olympic sized pool. This is where club practices, swimming lessons and other activities will be held, the primary use however will be practices and swimming meets. The size of the pool is so large because it will need to be able to provide enough space for large meets like state, and so athletes aren't swimming on top of each other during meet warmups or practices. It also will need to be able to hold a smaller diving well for those that are competing in diving.



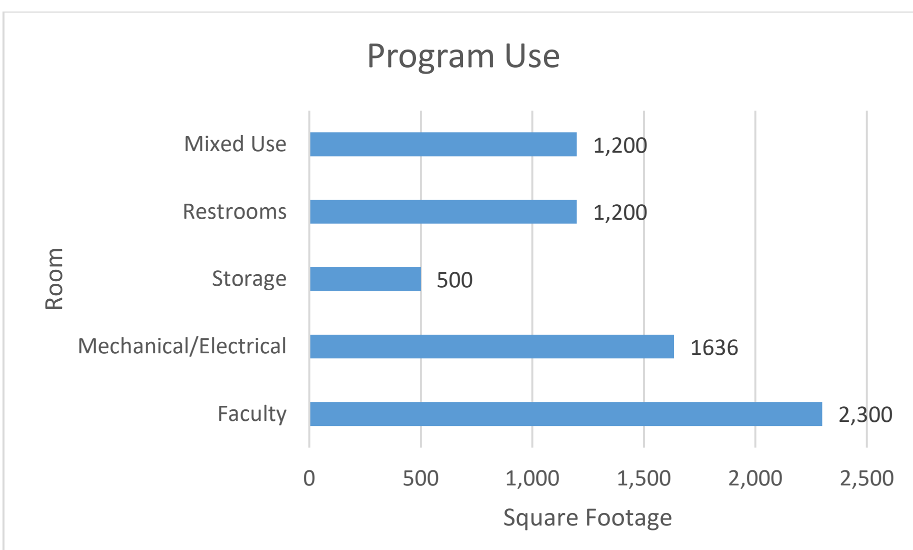


Figure 29: Program Use

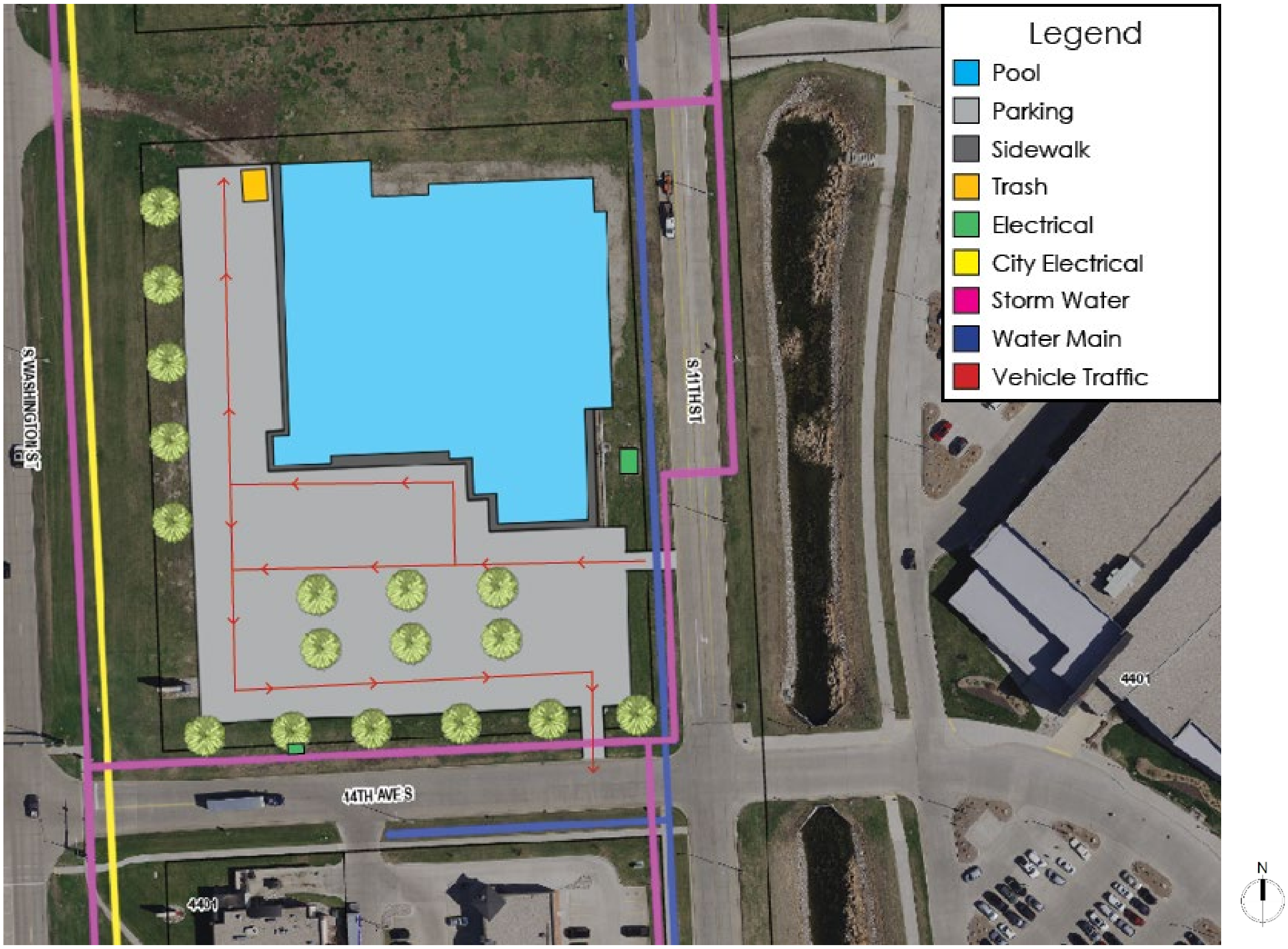


Figure 30: Site Layout

The orientation of the aquatic center will face south. This is done to get as much sunlight into the facility as possible, making the lobby and pool feel bright and uplifting. This will help with making the pool have a higher feel of energy for swimming meets, helping the swimmers compete at a much higher level than if the pool was dimmer and only used artificial lighting.

4. Results and Conclusions

4.1. Project Description

The Grand Forks Aquatic Center project is a study of the air circulation of an indoor natatorium and how to prevent water damage within the walls of the facility. This site was chosen because the indoor pools in Grand Forks are shutting down due to damage that is too expensive to repair. This has the potential to close many swimming programs that the city provides.

The primary focus of this project is to design the air circulation system. This system prevents the buildup of chlorine particles which cause respiratory problems if not maintained properly. It also is used to help keep the room at a comfortable temperature and slow the buildup of condensation which can get trapped within the walls, damaging them.

The secondary focus is to provide a well-designed natatorium for the club and high school teams to practice in and host larger meets. This will also be a facility for the community to use and provide swimming lessons for those new to swimming.

4.2. Project Objective

4.2.1. Air Circulation

The objective of this project is to design an air circulation system that properly circulates the chlorinated air of the pool with fresh air. Using SketchUp and Autodesk CFD I was able to design a system that seemingly circulates the air properly. Looking at the figures below they show how evenly the air is distributed throughout the room. This result was exactly what I was looking for in this project. This means that the air is being properly circulated preventing the air from becoming stagnant over time. Towards the pool deck we can see the exhaust circled in blue blowing air across the pool. This will constantly be blowing air throughout the day making sure the pool deck and surface of the water are also being changed with fresh air as this is the area with the most amount of chlorine particles. The next big accomplishment would be that the supply air circled in yellow is supplying air to the exterior walls. This prevents the buildup of condensation that would find its way into the interior of the wall causing wall deterioration.

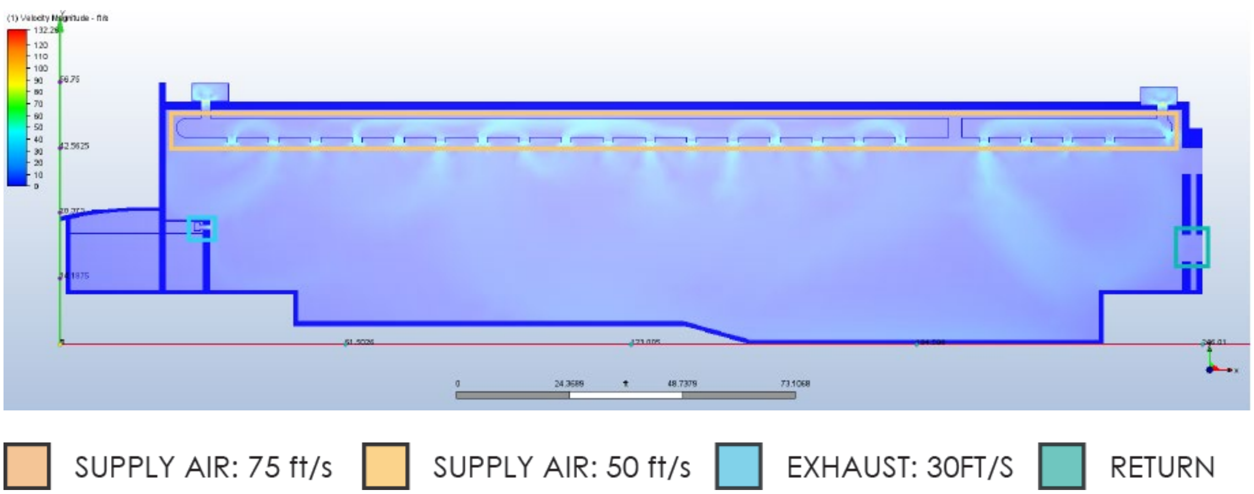


Figure 31: Pool Length Air Circulation

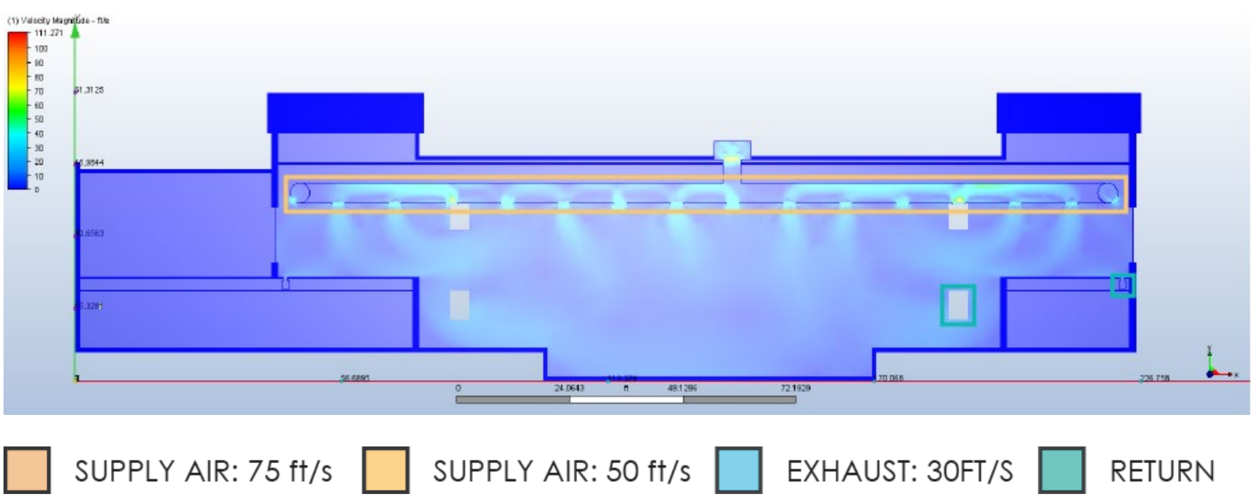


Figure 32: Shallow End Air Circulation

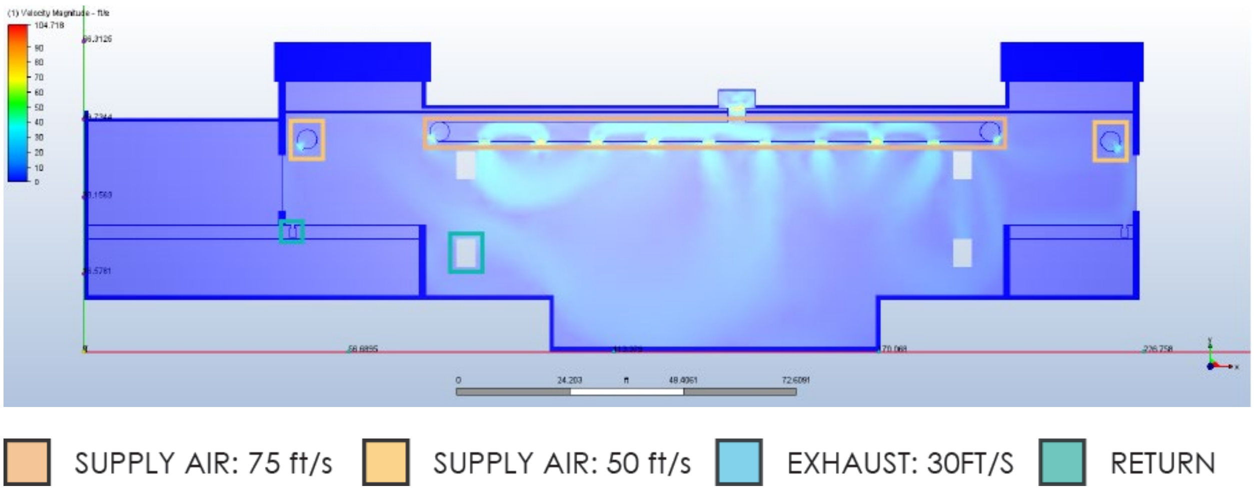
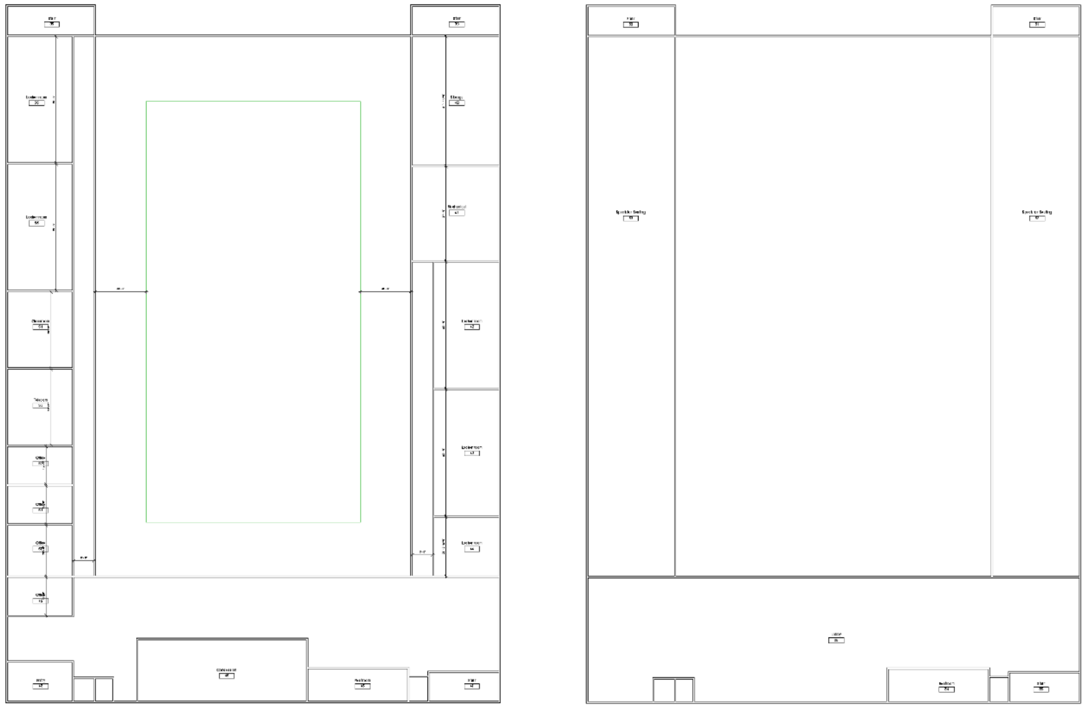


Figure 33: Deep End Air Circulation

4.3. Project Design

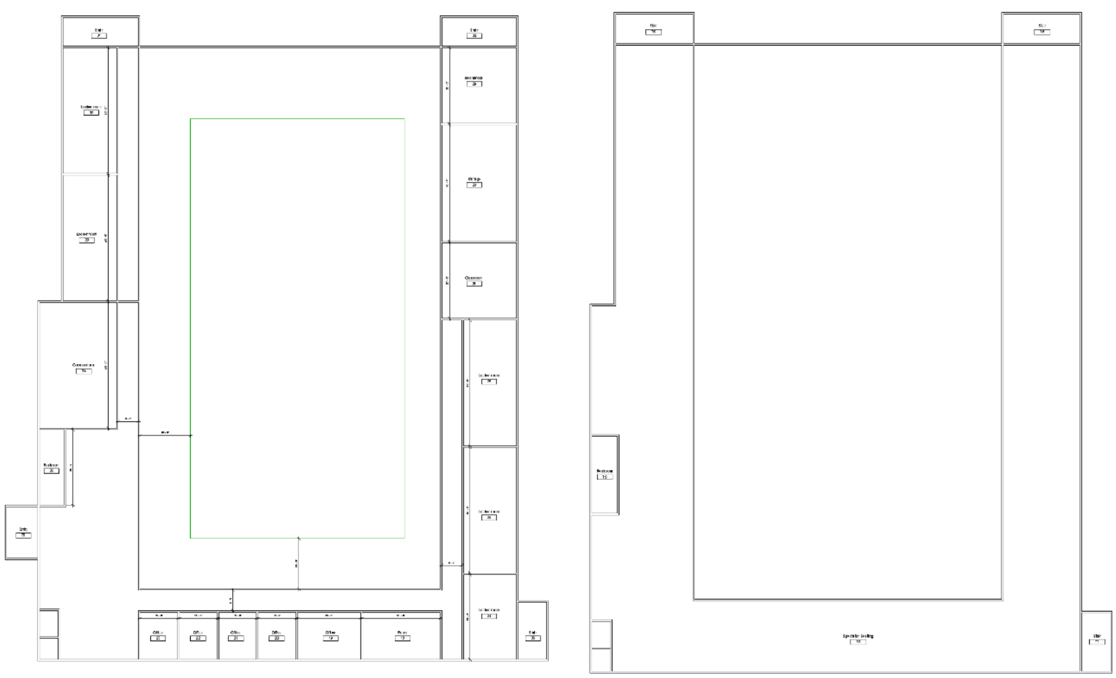
During the design phase of the project, I came up with seven different variants for the building layout. Using the Hulbert Aquatic Center and other elements of natatoriums around North Dakota as a basis. The goal for the floorplan of the building was to be able to come up with a layout that was easy to navigate. This allows for easy traversal around the facility, making it much easier for younger swimmers to navigate on their own and not be confused about where to go. Another big aspect of the design was to keep the faculty areas close to the main entrance of the facility. This way guests do not have to traverse the entire building to find an employee or coaches for questions guests may have.

For the final design of the floor plan, I used a combination of options six and seven. I believed these options had the easiest layout to follow while having plenty of space for the main lobby. By combining these two options together, I was able to condense the floor plan even more taking up less square footage as a result. This would allow for more green space on the site, giving kids enough space to run around outside.



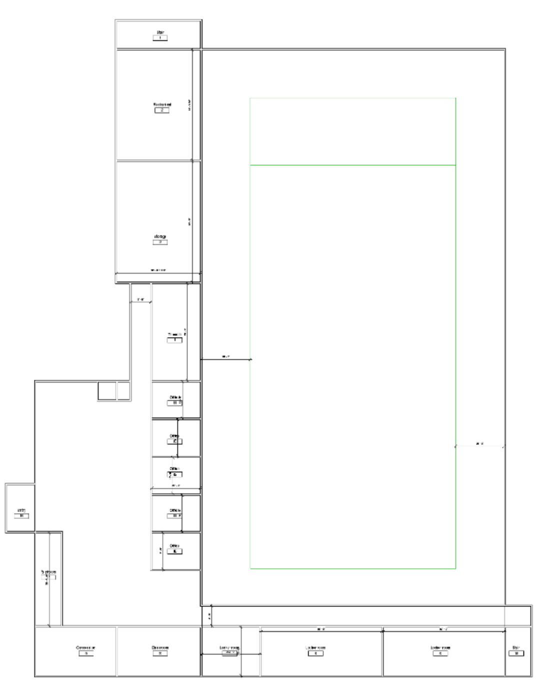
First Floor Second Floor

Figure 34: Iteration 1

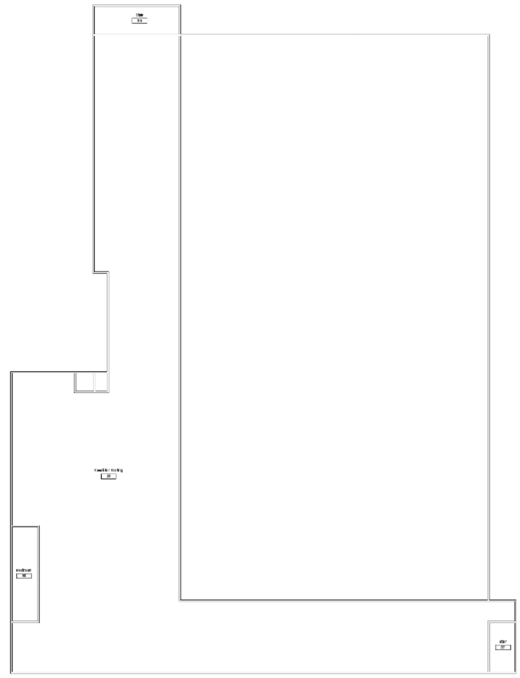


First Floor Second Floor

Figure 35: Iteration 2

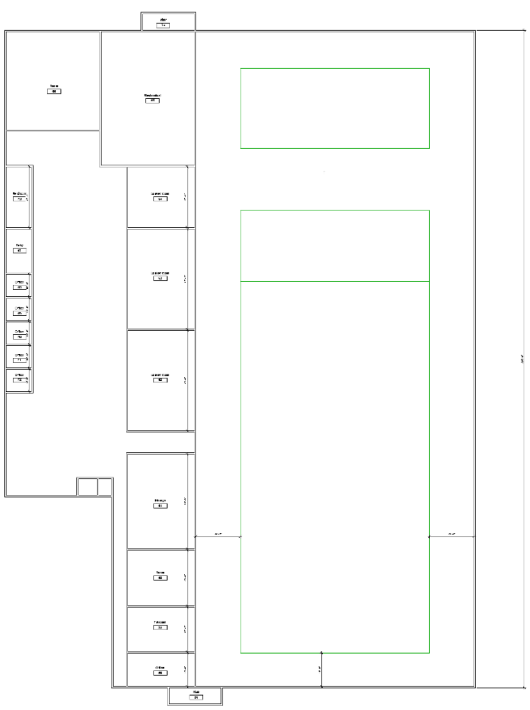


First Floor

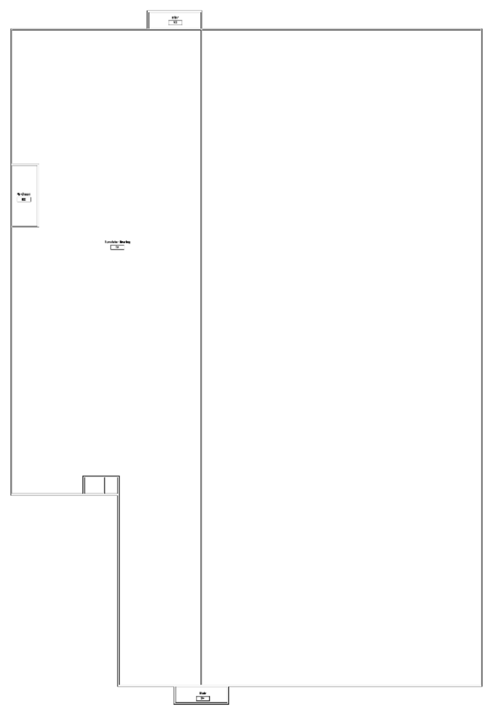


Second Floor

Figure 36: Iteration 3

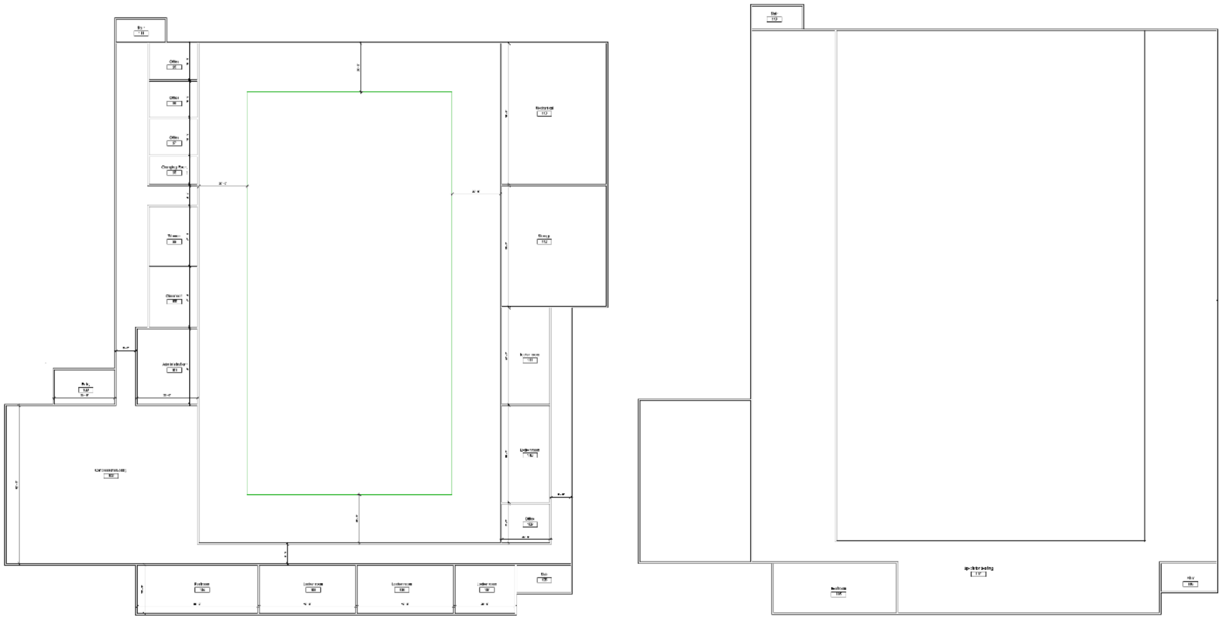


First Floor



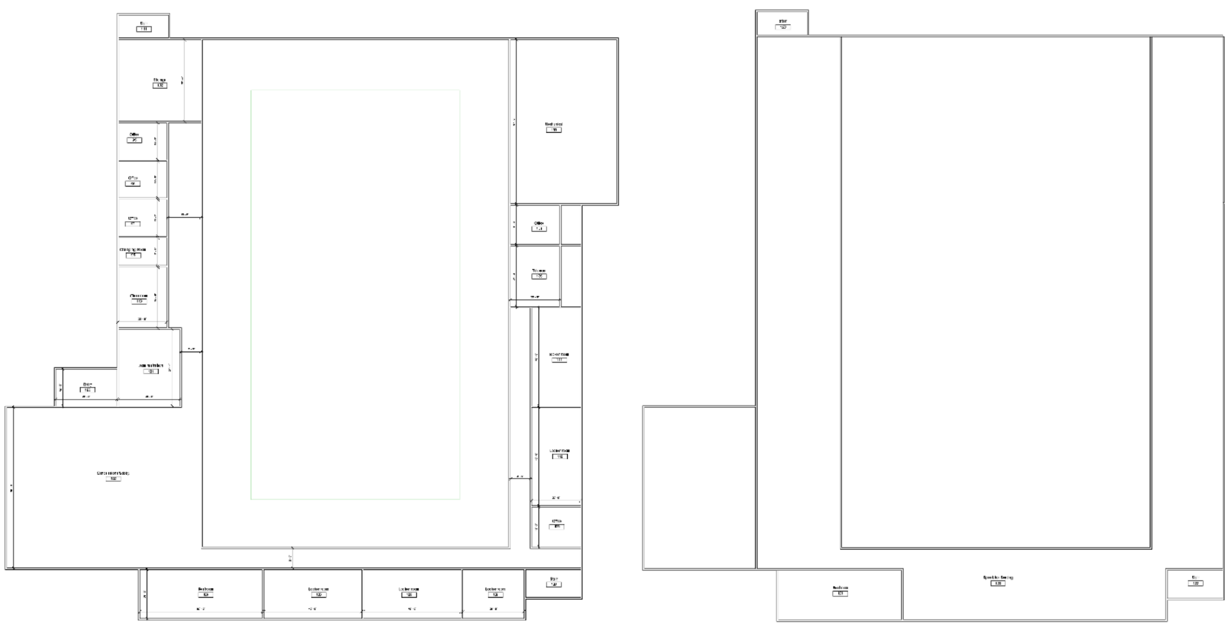
Second Floor

Figure 37: Iteration 4



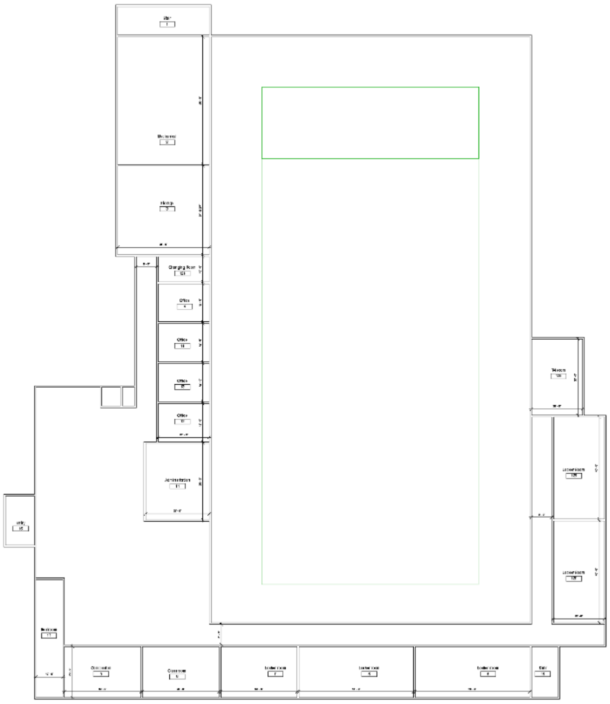
First Floor Second Floor

Figure 38: Iteration 5

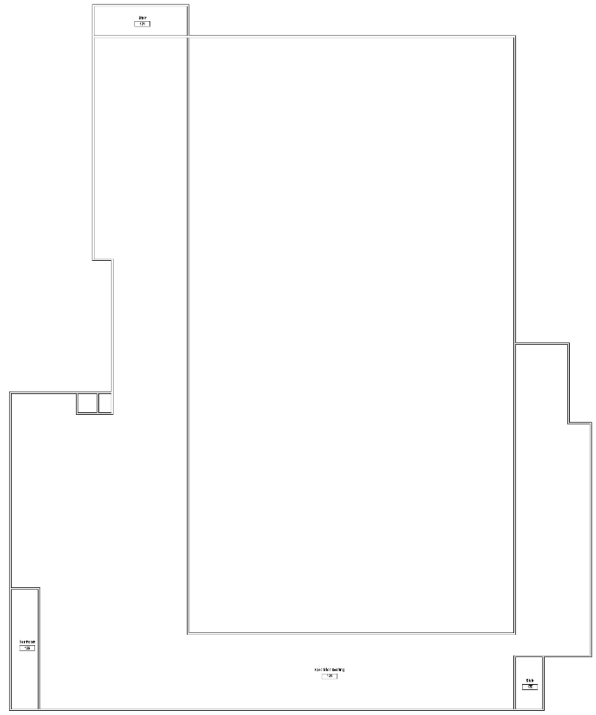


First Floor Second Floor

Figure 39: Iteration 6



First Floor



Second Floor

Figure 40: Iteration 7

4.3.1. Floor Plans

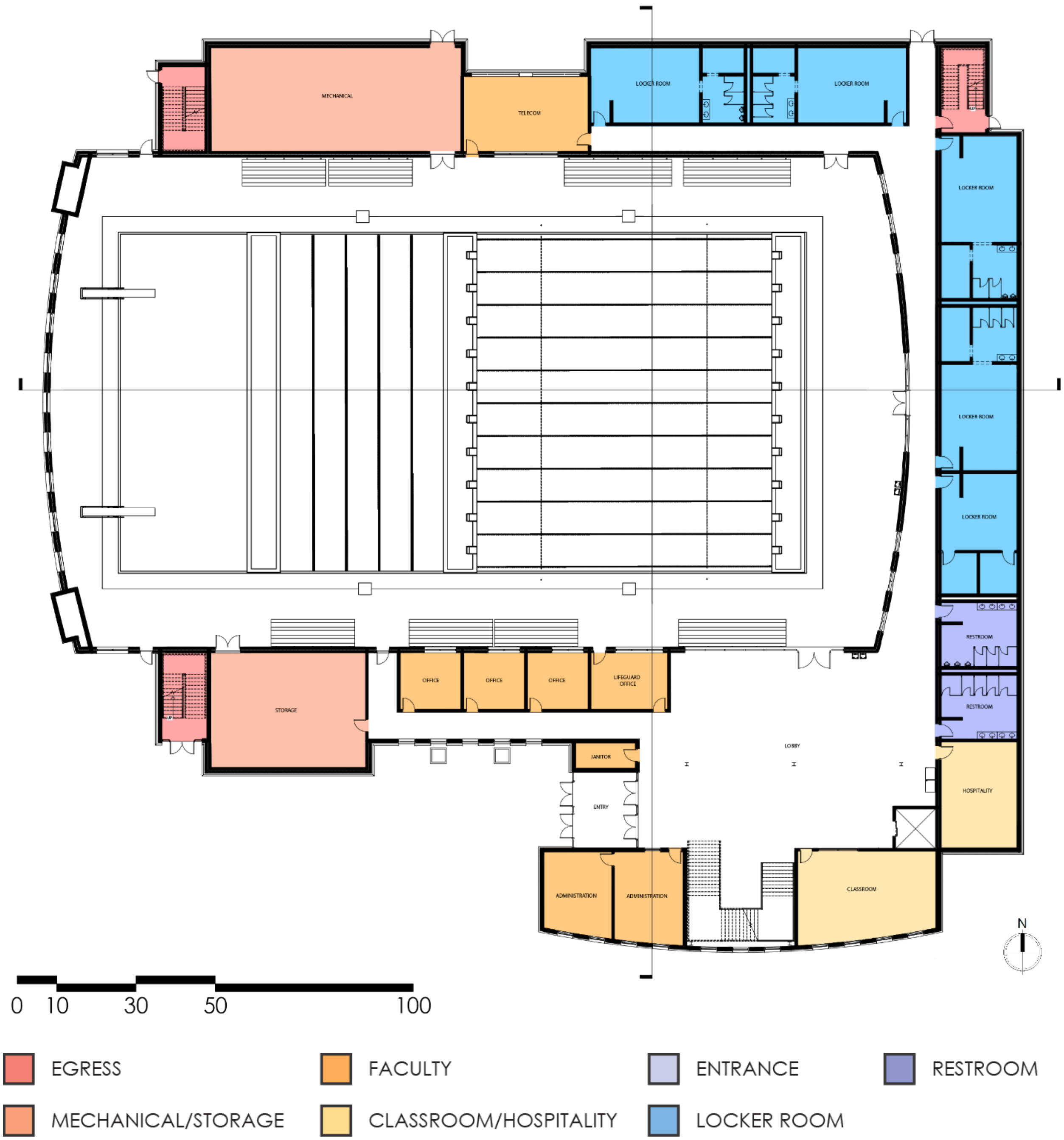


Figure 41: First Floor Plan

The main lobby on the ground floor is designed to be very spacious. This was done to accommodate for bigger swim meets or events that would be hosted. Having this space so large allows parents and other families to spread out and not feel so claustrophobic while waiting for their swimmer to change in the locker room. Another aspect that the lobby would be used for is an event space for the teams to use as a place for team bonding for state dinners or for the end of season award ceremonies.

The lobby also acts as a central hub for the facility. It connects to the coach's offices and administrative offices which are near the entrance of the building. Further back in the classroom, which will be used to hold meetings, train new lifeguards and other water-based training. Next to the classroom is a mixed-use room that will act as the hospitality room for coaches and officials during meets. Next are the locker rooms, there is one family locker room and four regular locker rooms. These were designed to feel very warm and inviting for visiting teams but more importantly the swimmers who are practicing here every day. This space is very important because it is where most of the team bonding takes place outside of the pool. Making sure it is a warm space with plenty of natural light was crucial for the swimmers to have a space to relax after hard practices and mentally recover as well.

As for the competition pool itself, it is a ten lane 50-meter-long Olympic sized pool. This allows for plenty of space to have swimming lessons and practice happening at the same time. The pool is sized this large for hosting long course in the summer and short course meets in the winter, allowing for a variety of competition training throughout the year. Any windows that are directly leading to the outside are frosted glass. This was done to help with the light diffusion of the pool so that no direct sunlight blinds the swimmers during a race, distracting them. The waves hanging in the ceiling are used as sound dampeners. This is included because the concrete masonry units (CMU) used to construct the building can make sound echo within the space making it very loud. They are also orientated with the length of the pool to help as a guide for newer swimmer's swim backstroke and not hit the lane ropes.

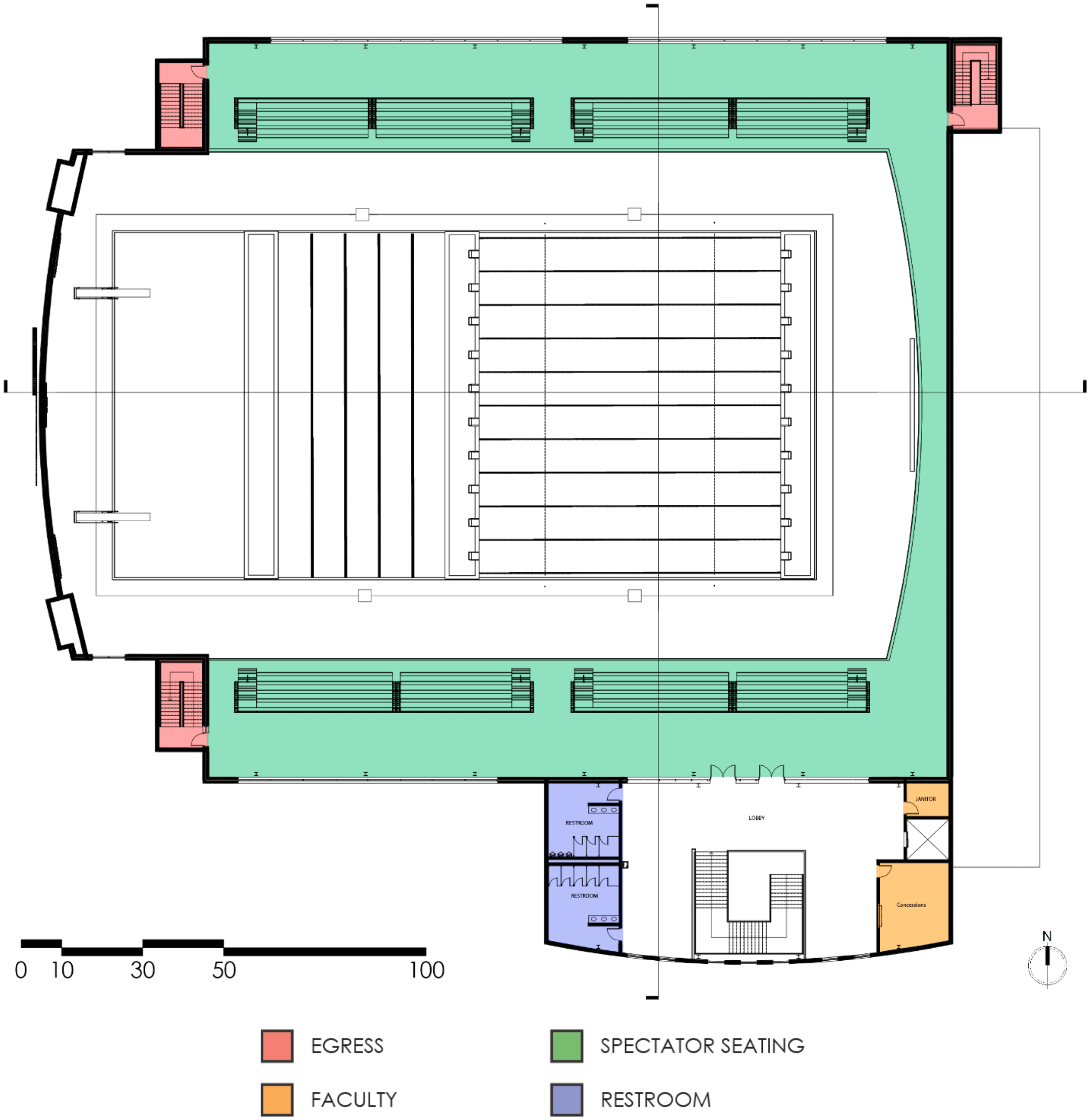


Figure 42: Second Floor Plan

4.3.2. Renders

Figure 43: Exterior View

Figure 44: Main Lobby

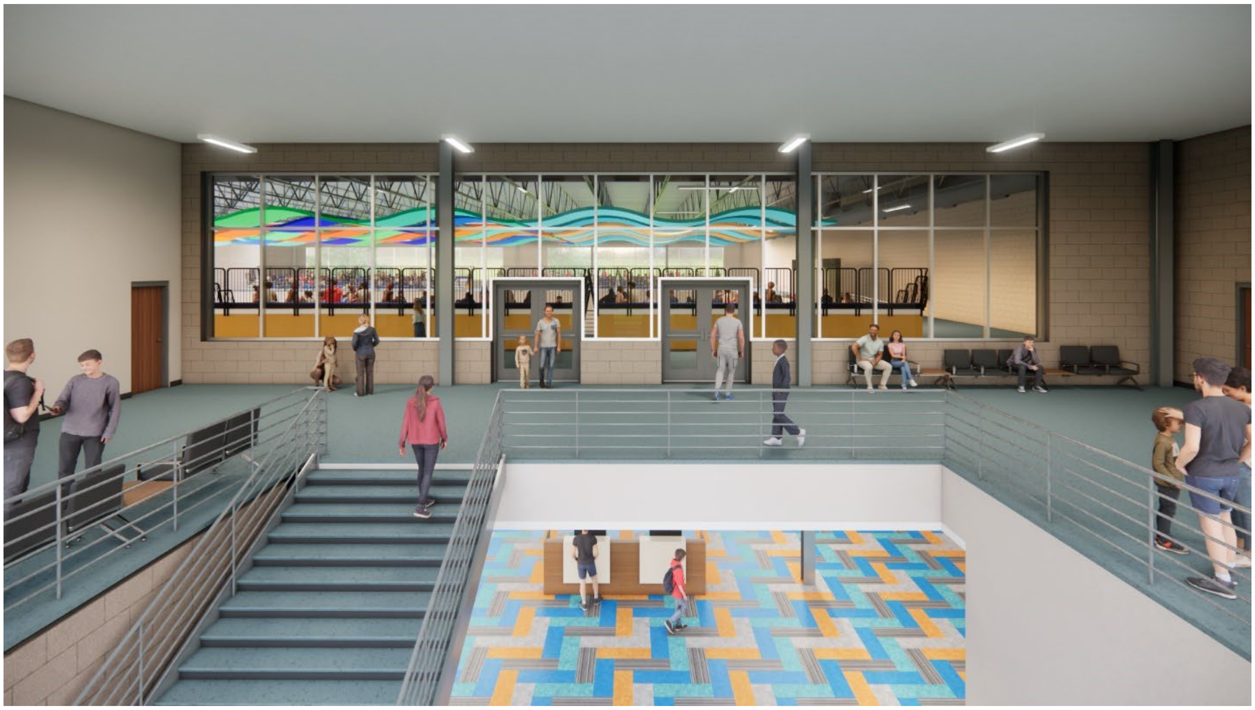


Figure 45: Upper Lobby

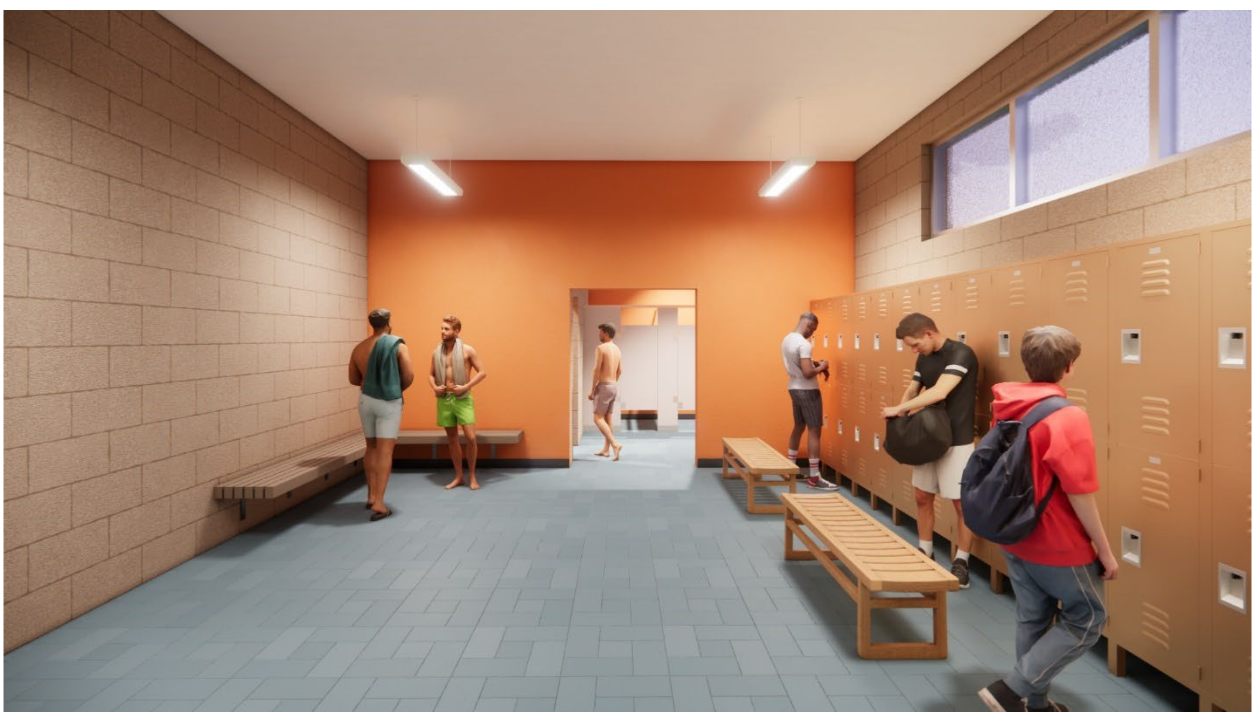


Figure 46: Locker Room

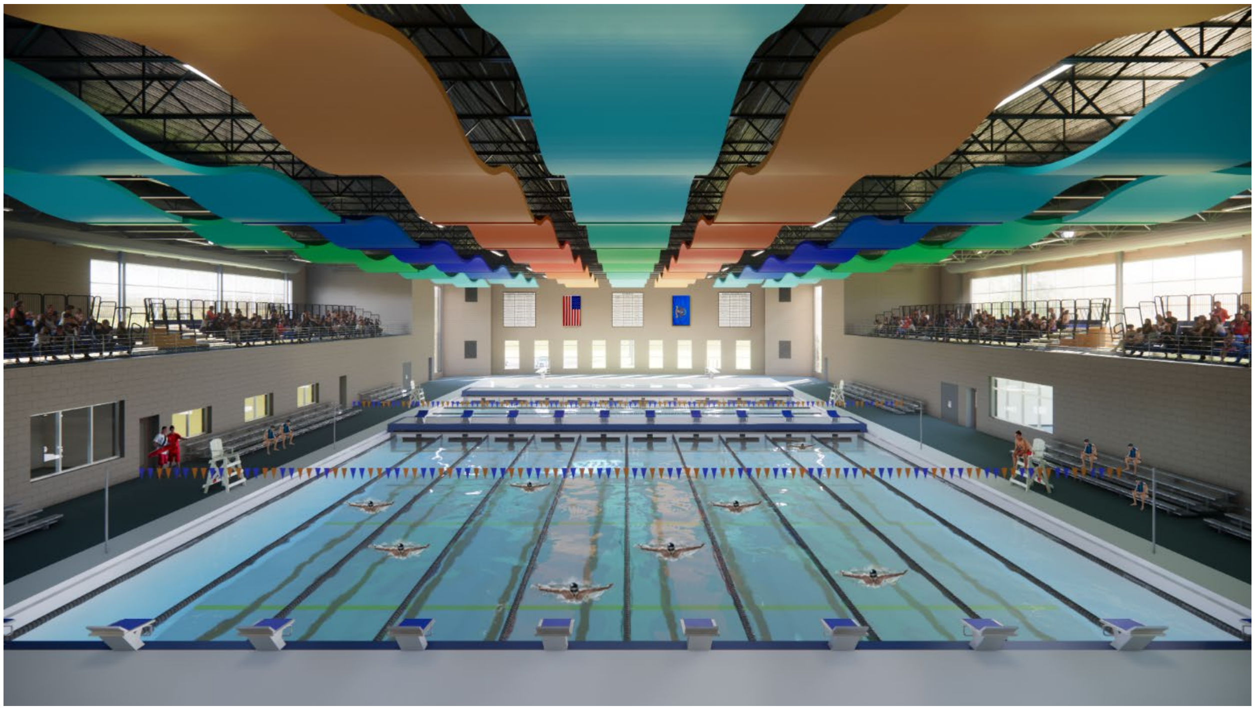


Figure 47: Natatorium View 1

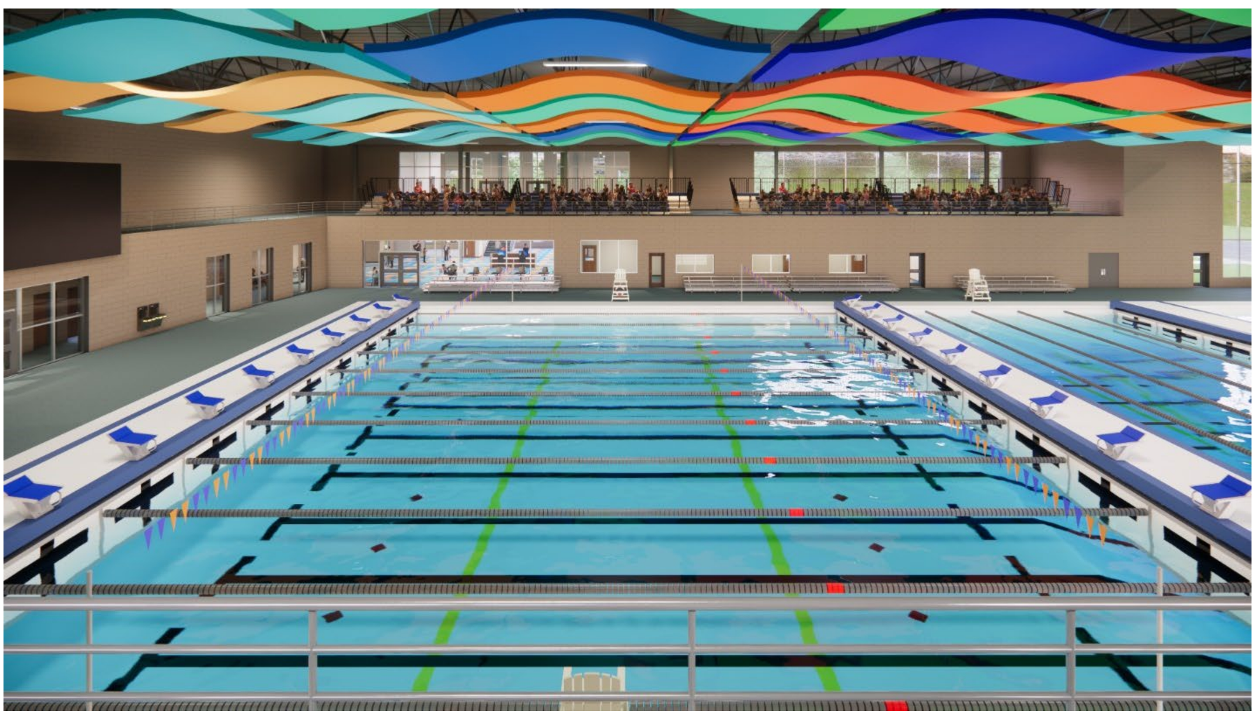


Figure 48: Natatorium View 2

4.3.3. Elevations

Figure 49: South Elevation

Figure 50: West Elevation

Figure 51: North Elevation

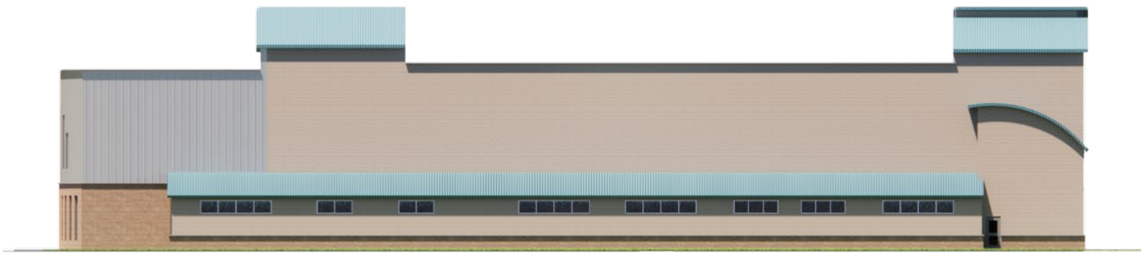


Figure 52: East Elevation

4.3.4. Section Cuts

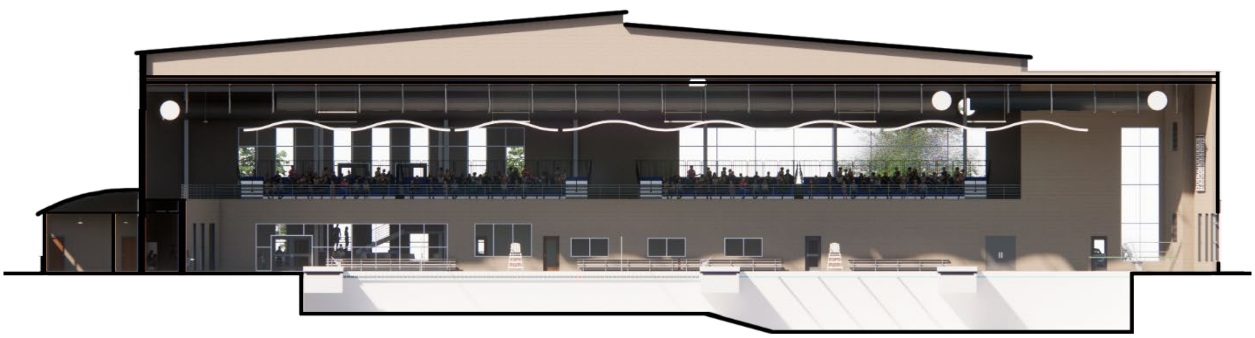


Figure 53: Section Cut

Figure 54: Cross Section

4.3.5. Structure

The design of the structure uses open web steel joists. These joists shown in Figure 55 are spaced apart in 9-foot spans and reach the width of the natatorium connecting to the walls highlighted in red. This is set at the 9-foot distance because of the required steel decking that is placed on top that the joists will be supporting along with the roof. The joists themselves will be resting on top of a steel beam that spans the length of the natatorium wall. The beam then transfers the load to the steel columns spaced out along the same wall then transferring said loads to the ground. The walls highlighted in blue in Figure 55 are where the joists for the roof connect to. This will have a similar support detail like the main structure of the building as shown in Figure 56.

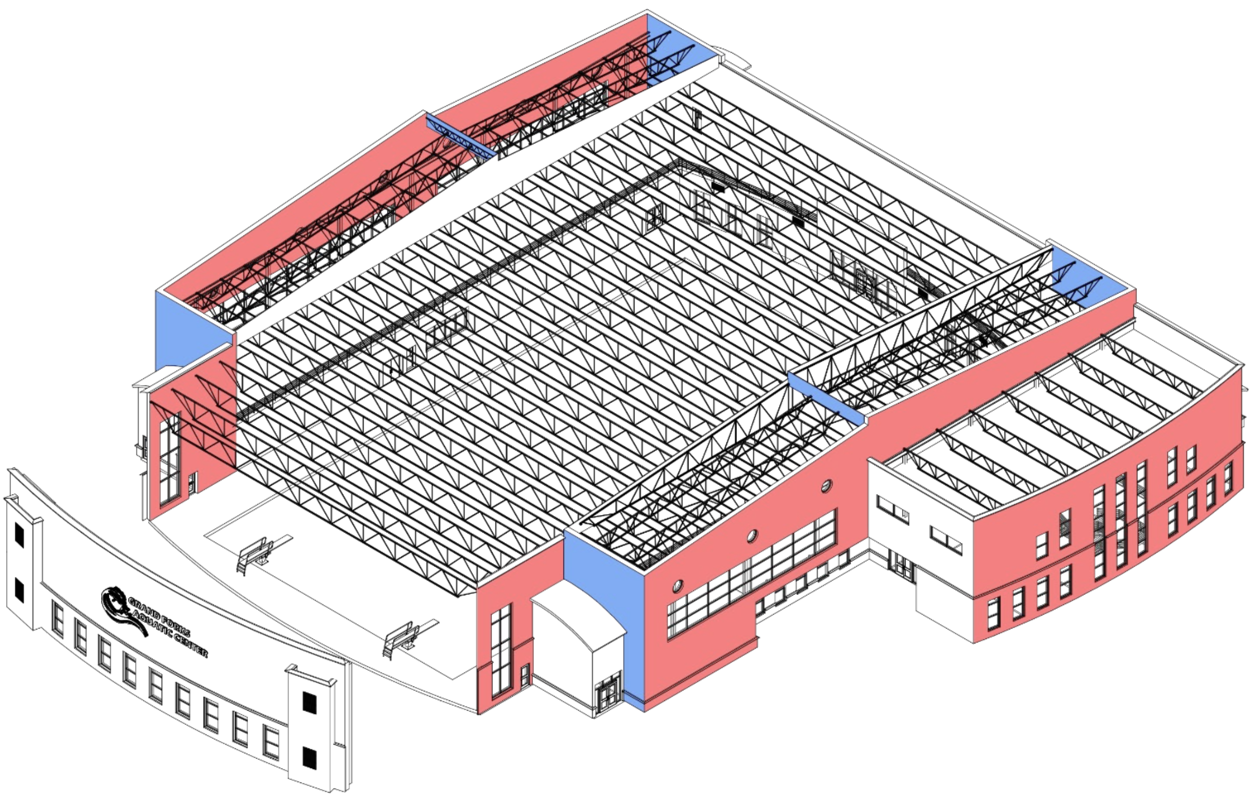


Figure 55: Structure Diagram

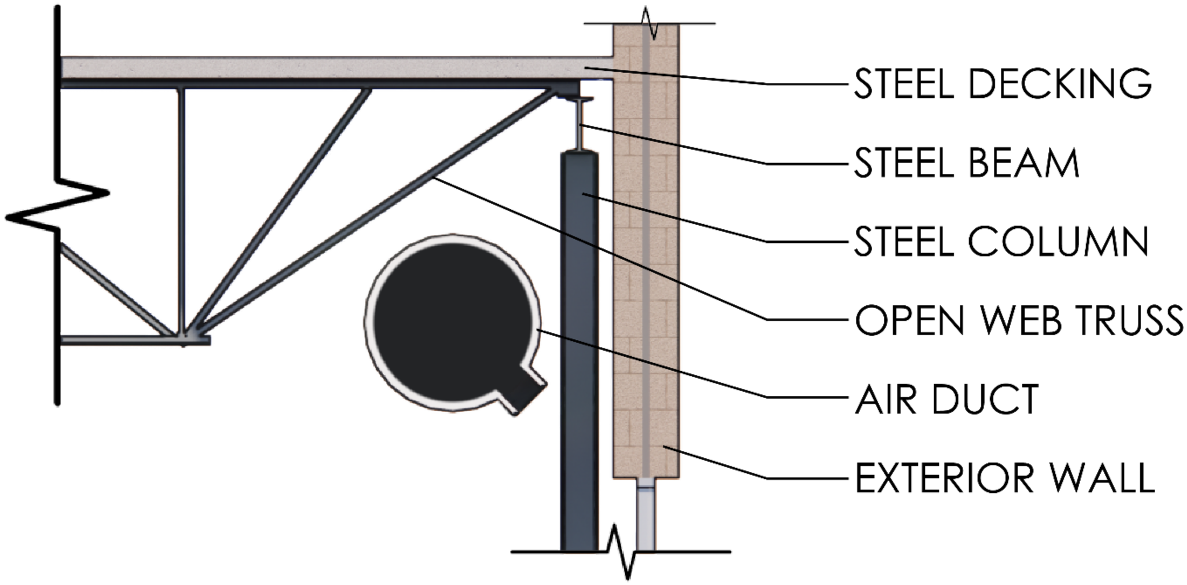


Figure 56: Support Detail

4.3.6. HVAC Design

The design of the HVAC system takes the “U” shape design suggested by the Desert Air Pool Design Guide. This design allows for a majority of the walls to be hit with constant air flow preventing condensation on the walls and not allowing moisture to find its way in causing interior wall damage. The ducts highlighted in yellow shown in Figure 57 are set to the minimum of 50ft/s for air flow. These are also the ducts closest to the walls and are constantly blowing air on them again to prevent condensation and interior damage. The ducts highlighted in orange are set to 75ft/s for air flow. The purpose of this system is to cool the spectators and to circulate the rest of the air in the pool to help prevent the air from settling and becoming stale. In the blue is the exhaust that constantly blows air across the pool deck pushing the higher concentration of chlorinated air particles to the return ducts highlighted in green. This is where the air will be filtered through and released to the outdoors as fresh air.

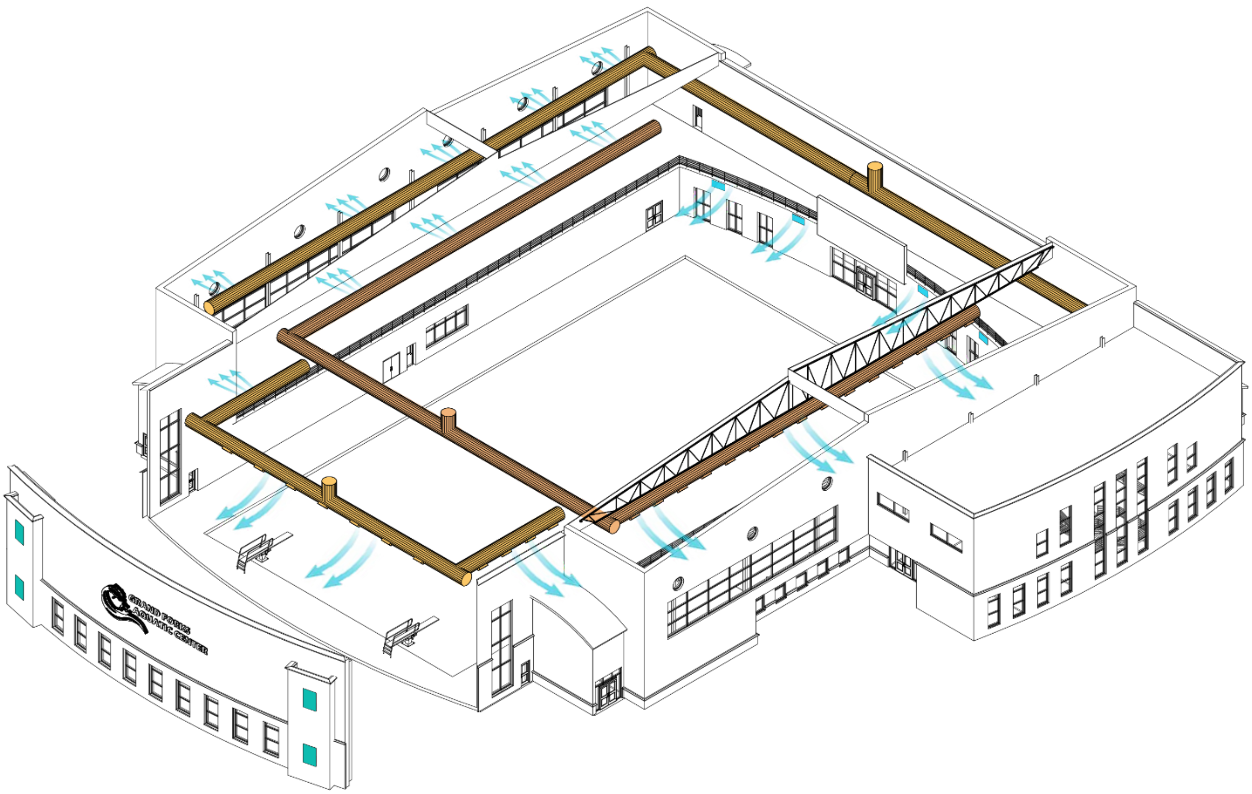


Figure 57: Air Circulation System

4.3.7. Wall Details

To prevent damage to the interior of the wall, a vapor retarder is used to keep moisture from finding its way inside. The other aspect to keep in mind is that the vapor retarder must be set on the warmest side of the wall. As North Dakota is a seasonal state with it being winter for most of the year the warmest side in this case would be the interior side. The vapor retarder combined with the HVAC system should in theory have very little moisture problems during its life cycle.

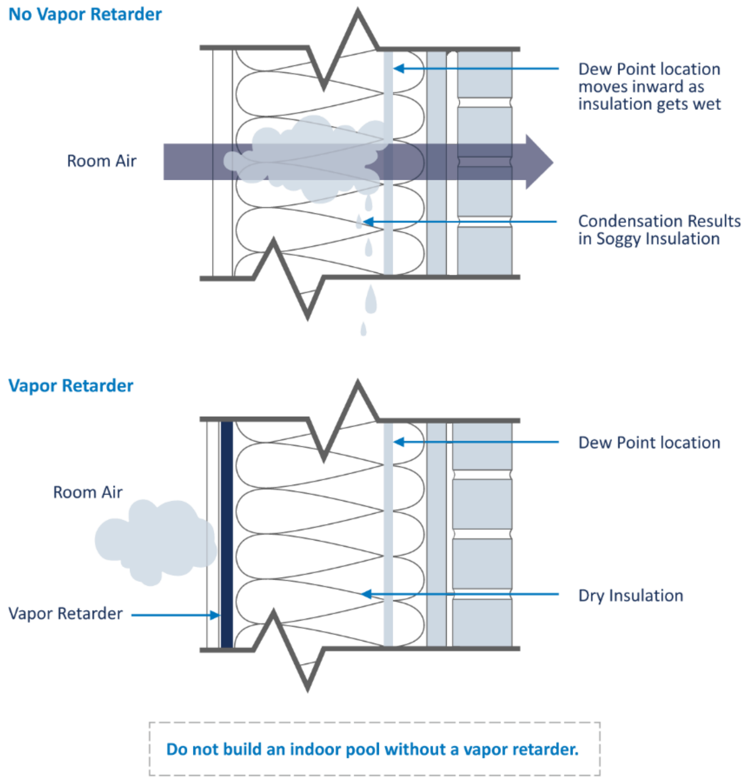


Figure 58: Vaper Retarder Detail

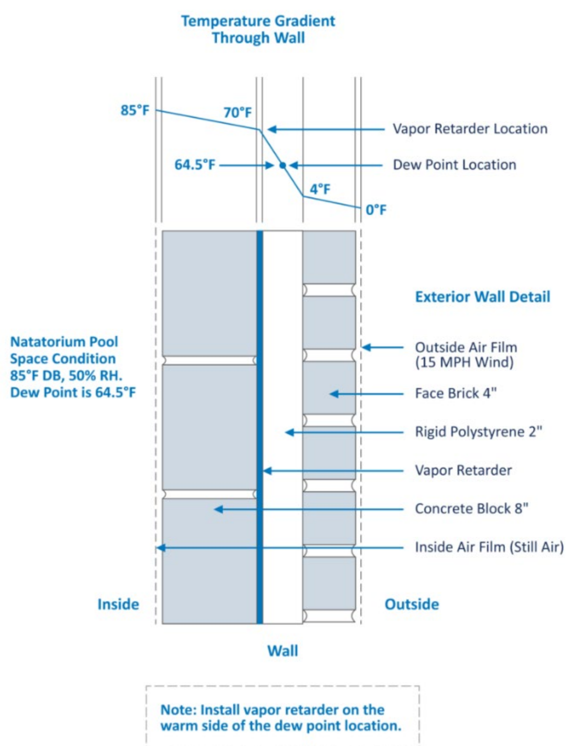


Figure 59: Wall Detail

4.4. Conclusions

The overall process of designing this project was challenging but very rewarding. The biggest challenges for this project were designing the structure of the building itself and the air circulation system. The structure had to be done correctly to be able to make sure that the building would be able to stand on its own but also have the HVAC system be able to run through the joists that hold up the ceiling and roof. By not understanding how the structure worked the project overall would not have been as successful as it has turned out.

The problem of using a three-dimensional model in Autodesk CFD was not solved for this project. This would have helped the project greatly to see how the air circulates within the environment allowing for a greater understanding of any underlying issues that may have come up the final HVAC system was able to provide.

If anything could be added to this project, it would be a heat and moisture study. A heat study would help develop the HVAC design even further by showing if the air circulating within the building is properly cooling all areas of the pool. The moisture study would help visualize how well the walls are preventing moisture from getting into them while also showing if the HVAC system has enough air flow to mediate the buildup of condensation.

BIBLIOGRAPHY

2D Sun-Path. (n.d.). Retrieved May 5, 2024, from https://andrewmarsh.com/apps/releases/sunpath2d.html

09.09.2016—Presentation Floor Plans.pdf. (n.d.). Retrieved May 5, 2024, from https://www.swimwestfargo.com/images/PLAN/09.09.2016%20-%20Presentation%20Floor%20Plans.pdf

akrherz@iastate.edu, daryl herzmann. (n.d.). *IEM: Site Wind Roses*. Retrieved May 5, 2024, from https://mesonet.agron.iastate.edu/sites/windrose.phtml?station=GFK&network=ND_ASOS

Brochure-21st-Century-Pool-Design-Guide-DA030.pdf. (n.d.). Retrieved November 25, 2023, from https://www.desert-aire.com/sites/default/files/Brochure-21st-Century-Pool-Design-Guide-DA030.pdf

Consulting, C. (n.d.). *Five Common Mistakes in Natatorium Design*. Retrieved September 1, 2023, from https://blog.chloramineconsulting.com/five-common-mistakes-in-natatorium-design

Facility Features / Competition Pool. (n.d.). Retrieved May 5, 2024, from https://www.west-fargo.k12.nd.us/Page/http%3A%2F%2Fwww.west-fargo.k12.nd.us%2Fsite%2Fdefault.aspx%3FPageID%3D4999

Lomax, M. (2016). Airway dysfunction in elite swimmers: Prevalence, impact, and challenges. *Open Access Journal of Sports Medicine*, *7*, 55–63. https://doi.org/10.2147/OAJSM.S88339

Natatorium Design Guide. (n.d.). Dehumidified Air Solutions. Retrieved August 30, 2023, from https://dehumidifiedairsolutions.com/natatorium-design-guide/

UP Aquatics. (n.d.). Retrieved May 5, 2024, from https://www.swimwestfargo.com/plan.html

USA-Swimming-THE-AIR-QUALITY-ISSUE.pdf. (n.d.). Retrieved September 6, 2023, from https://cdn2.hubspot.net/hubfs/5079918/USA-Swimming-THE-AIR-QUALITY-ISSUE.pdf

Weather averages Grand Forks, North Dakota. (n.d.). Retrieved May 5, 2024, from https://www.usclimatedata.com/climate/grand-forks/north-dakota/united-states/usnd0476

APPENDIX: TIMELINE

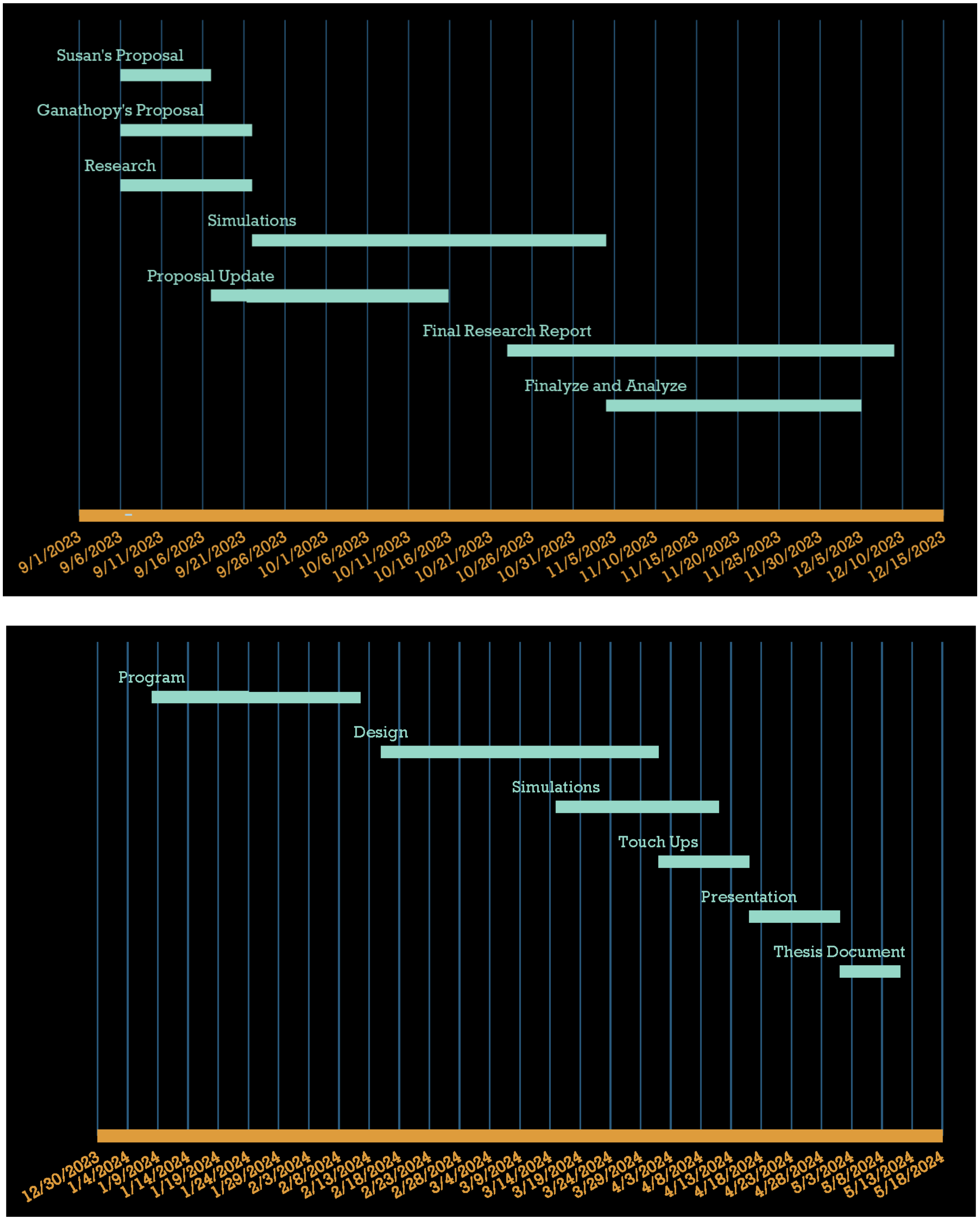


Figure A1. Timeline