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Title

THE INTERSECTION OF NATURE AND KNOWLEDGE: RED RIVER VALLEY SCIENCE CENTER

By

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MASTER OF ARCHITECTURE

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THE INTERSECTION OF NATURE AND KNOWLEDGE: RED RIVER VALLEY SCIENCE CENTER

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ABSTRACT

This thesis investigates the establishment of a Natural Science Center in Fargo, North Dakota, as a dynamic hub for informal learning and community engagement. Emphasizing biophilic design, the center integrates natural elements into its architecture and exhibits, creating a space that is not only educational but also health-promoting and psychologically beneficial. The project positions the center as a vital cultural and community hub, fostering a deeper connection between residents and the natural world. It explores how this integration can stimulate learning, enhance community bonding, and reinforce local cultural identity. The study further examines the broader impacts of the center, including societal, economic, and political influences, positioning it as a catalyst for urban development and environmental stewardship. This research aims to conceptualize the comprehensive role of Science Centers in urban environments, focusing on their capacity to enrich personal development, societal engagement, and economic prosperity.

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$ .... United States Dollar sign

&.. And

%.. Percentage

INTRODUCTION

In the midst of rapid urban expansion, where the connection between individuals and the natural world often fades, lies an opportunity to foster informal learning—a form of learning that is voluntary, self-motivated, and embedded in daily life. This thesis investigates the potential of a Natural Science Center in Fargo, North Dakota, to cultivate this type of learning within the community. Grounded in the principles of biophilic design and biomimicry, the envisioned center aims to reintegrate nature into the urban landscape, not merely as an aesthetic feature but as an interactive educational tool that encourages spontaneous discovery and imparts knowledge beyond formal educational settings.

Biophilic design, which seamlessly incorporates natural elements into man-made environments, transcends mere visual enhancement, offering tangible health and psychological benefits. When coupled with biomimicry—innovation inspired by nature's models and systems—these design principles can create spaces that inherently stimulate informal learning. Visitors of the center will not only gain insights into ecological and biological sciences but also engage in a learning journey that emphasizes observation, experience, and reflection, which are key components of lifelong learning.

Moreover, such a center stands as a powerful statement against climate change, offering the local economy a boost, enhancing community well-being, and promoting sustainable practices. It becomes more than a place; it becomes an experience that informs, connects, and inspires action, embodying the essence of informal learning by making education a part of the community's fabric.

Problem Statement

As urban areas, like Fargo, North Dakota, continue to expand and evolve, the relationship between communities and the realm of science encounters new challenges and opportunities. According to Mark Williams, Fargo’s Assistant Planning Director, Fargo has seen its population grow by 105% and its land area increase by 97% since 1980. This rapid growth exemplifies the challenges and potentials of urban sprawl, emphasizing the increasingly significant role of Science Centers. These centers, traditionally viewed as educational venues, are now pivotal in fostering informal learning, community engagement, urban development, and environmental stewardship. This thesis investigates how a Science Center in Fargo can bridge the gap between the community and the expanding scientific horizon. This is especially pertinent given the city's close association with several universities that could collaborate and contribute intellectual resources. The research examines the role of the center in addressing the dynamic needs of a growing city, highlighting the benefits of science and technology in the face of rapid urban expansion. While many cities globally have recognized the benefits of Science Centers, Fargo, with its unique urban, natural, and agricultural blend, lacks such a space. This thesis seeks to understand how a Science Center in Fargo can enrich the local community, acting as a catalyst for fostering a rich environment for informal learning, community development, and environmental awareness.

Research Question(s):

- In what ways can a Science Center promote local economic growth, community well-being, and community education?
- How can a Science Center based on biophilic design and biomimetic principles enhance the learning experience, foster a deeper connection between individuals and nature, and promote sustainable behaviors and awareness?

Proposed Outcomes

Deliverables:

- Develop criteria for Science Centers that embody biophilic and biomimetic principles to create an environment conducive to learning, encourage community bonding, and promote sustainability.
- A Natural Science Center designed to serve as a cornerstone for community engagement, stimulate local economic growth, deepen connections with nature, and enhance informal learning opportunities.

Impact: The envisioned Science Center, with its focus on the natural world, aims to be more than just a building, it seeks to stand as a vibrant symbol of the fusion of community, the natural and the built environment, and architectural ingenuity. Poised to be a beacon for community development, economic growth, and environmental stewardship, the center will be designed to foster a rich environment for informal learning. Its mission extends beyond the traditional boundaries of education, aiming to inspire a generation to be more in tune with nature through engaging, hands-on experiences that promote understanding and appreciation of the natural world. Through its various programs and exhibits, the center will encourage visitors of all ages to explore, question, and learn, thereby creating a space where informal learning becomes a key tool for environmental awareness and community empowerment.

Objective

This research aims to conceptualize the multifaceted role of Science Centers in contemporary urban settings. It focuses on understanding how these centers address the challenges of urbanization and become integral parts of the communities they serve. The goal is to understand their comprehensive impact on personal development, societal and economic enrichment, and political engagement.

BACKGROUND

As we navigate the complexities of the twenty-first century, urban communities worldwide confront a unique set of challenges and opportunities. The rapid expansion of cities and the evolution of technology have reshaped our interaction with the natural world and scientific inquiry. In this era of unprecedented urbanization and technological advancement, the role of Science Centers emerges as both pivotal and transformative.

Historically, Science Centers have been perceived primarily as educational and recreational facilities. However, their potential extends far beyond. These institutions represent a critical nexus between science, community, and the environment, fostering a culture of curiosity, learning, and societal engagement. The Industrial Revolution and subsequent technological advancements have often distanced urban populations from the natural world. Science centers, through their interactive and immersive experiences, offer a bridge to reconnect people with nature and science in meaningful ways.

My journey of exploring the profound impact of Science Centers began with an observation: the stark contrast between the vibrancy of these centers and the often sterile, isolated environments of traditional educational settings. Why do we confine learning within four walls, away from the dynamic world it aims to understand? This question led me to dive deeper into the philosophy and architecture of these unique spaces.

This thesis is inspired by the potential of Science Centers to act as beacons of knowledge, community cohesion, and environmental stewardship in urban settings. It seeks to unravel how these centers can transform the urban fabric, not just by being centers of learning, but by being catalysts for community development, economic growth, and environmental awareness. These centers can break the barriers between indoor and outdoor learning, bringing the community into a shared space of discovery and inspiration.

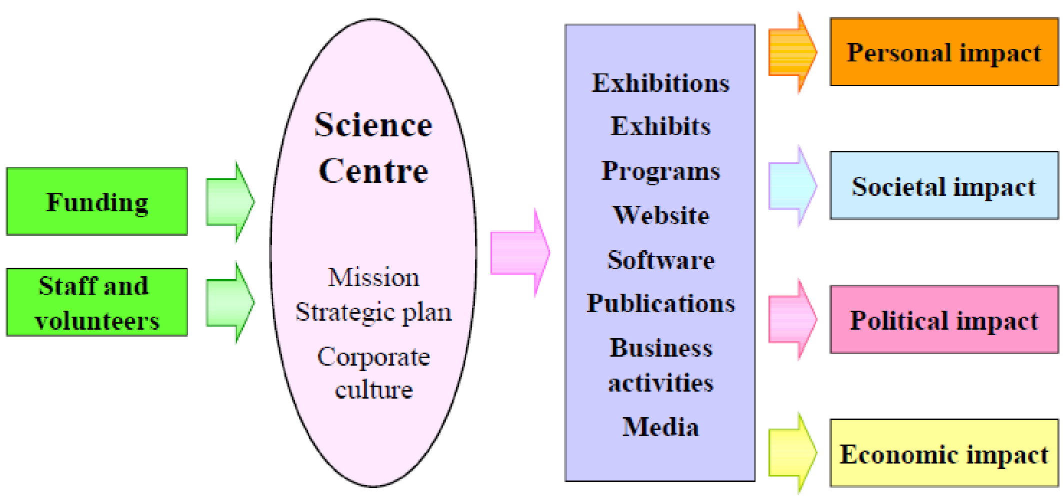
The central premise of this study is that Science Centers are not mere repositories of knowledge or passive spaces for observation. They are active, living entities that engage with and respond to their urban context. They serve as mirrors reflecting the community's aspirations and challenges, and as windows opening to new possibilities in harmonizing our relationship with science and nature. This thesis will explore the dynamic role of Science Centers as vital components of urban landscapes, exploring their potential to influence the trajectory of urban development and community well-being. It seeks to understand how these centers can become essential parts of urban life, fostering meaningful connections between people and the natural world around them.

Previous Research

Science Centers and Their Impacts

Science centers serve as important platforms for science education, engagement, and community development. They provide opportunities for hands-on learning and experimentation, allowing visitors to actively participate in the scientific process. Science Centers have been found to positively impact long-term interest, knowledge, and engagement in science (Garnett, 2002). According to Garnett, Science Centers play a significant role in impacting both individuals and communities. These impacts can be classified into four categories: personal, societal, economic, and political.

Figure 1. Model of Science Center Impacts



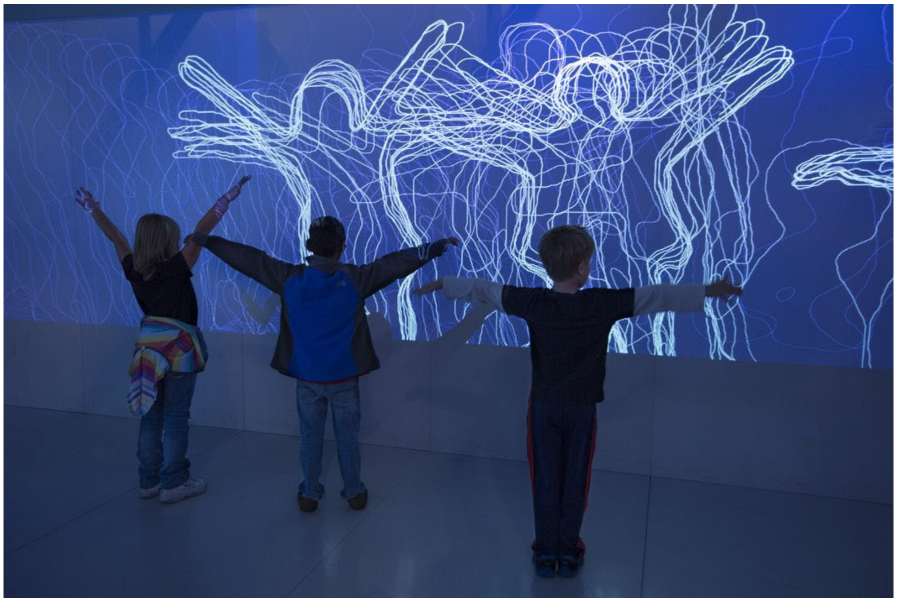
Note: *From The impact of Science Centers/Museums on their Surrounding Communities: Summary Report. By R. Garnett, 2002, Kingston: Questacon. (chrome extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.ecsite.eu/sites/default/files/impact_study02.pdf)*

This Model provides a structured framework for understanding how these institutions function and their broad-ranging effects on communities. The backbone of its daily operations is supported by funding, staff, and volunteers. At its core, the model illustrates that a Science Center operates based on its mission and strategic plan, supported by a corporate structure. The Science Center, through these resources, produces outputs. These outputs include various exhibitions, educational programs, and digital resources (Garnett, 2002). These outputs generated by the Science Center have significant impacts on the community and visitors that it serves. Measuring these impacts provides evidence of the Science Center's value and effectiveness to the community and stakeholders. It's a cycle of input, output, and impact assessment that continually reinforces the Science Center's role and importance in fostering community engagement, education, and development. (Garnett, 2002)

Personal Impacts of Science Centers. Perhaps the largest impact a Science Center has, is on the visitor itself. The personal impact of a Science Center refers to the transformation that takes place within an individual as a result of their interaction with the Science Center **(Garnett, 2002)**. These institutions are pivotal in shaping individual learning experiences and attitudes toward science. They provide unique environments where personal enjoyment, career direction, and professional expertise can be developed. Importantly, they often act as catalysts for changing attitudes toward science, enhancing social experiences, and guiding career paths (Garnett, 2002).

Further emphasizing this impact, Allalouf & Alderoqui-Pinus, highlights how Science Centers inspire visitors to think creatively and explore new ideas. The interactive and immersive nature of these centers engages visitors with scientific concepts in a hands-on manner, fostering curiosity and encouraging outside-the-box thinking. This approach is instrumental in developing critical thinking and problem-solving skills, crucial for those interested in STEM fields (Allalouf & Alderoqui-Pinus, 2012).

Figure 2. Interactive YOU! Exhibit



Note: *Interactive wall in the YOU! Exhibit at the Museum of Science and Industry in Chicago. From YOU! The Experience, (https://www.msichicago.org/explore/whats-here/exhibits/you-the-experience/)*

Beginning in the 1980s, funders in the United States, including the National Science Foundation (NSF), initiated support for informal science education initiatives aimed at girls, with the goal of sparking their interest in science and potentially leading them to choose science-based careers. The research project *Cascading Influences* conducted in 2013 by Dale McCreedy & Lynn Dierking, investigated the impact of gender-focused informal science programs on young women's decisions to pursue science careers or science-oriented hobbies. This study, which involved participants from six museum-related initiatives targeting girls from underserved communities, adopted a Community of Practice (CoP) framework, emphasizing knowledge domains, shared practices, and communal learning.

Figure 3. Self-eSTEM Girls Camp Visiting the Exploratorium

Note: *From Kathleen Maclay, Girls' STEM camp connects with campus (https://news.berkeley.edu/2017/08/31/girls-stem-camp-connects-with-campus)*

The findings showed that 48% of the participants were working in STEM-related careers, and over half (53%) pursued STEM majors in college, significantly higher than the national average for first-year female undergraduates. The study highlighted the importance of informal science learning experiences in influencing young women's career paths and personal development in STEM fields. Notably, the program impacted personal development for 53% of the participants and influenced the career goals or future aspirations of 24% of them. Some of the long-term impacts included increased understanding and enjoyment of science, enhanced skills, and stronger social networks. Participants also reported increased confidence, self-esteem, and changes in identity, reflecting the profound influence of these programs on their personal and professional lives. The study highlighted the importance of these experiences in shaping science-informed citizens and engaged science participants, underscoring the role of Science Centers in fostering science identities and career choices in young women (McCreedy &

Dierking, 2013). Parallel to this, Hannu Salmi's broader study on informal learning in Science Centers, not specifically gender-focused, indicated that such informal learning sources significantly influence academic and career choices in science and technology fields. These Science Centers, known for creating memorable experiences, often generate strong emotions and leave lasting impressions, thereby influencing interests, engagement, and participation in science and technology. (Salmi, 2003) Overall, these findings underscore the positive impact of informal science education programs in fostering lasting interest and engagement in STEM, particularly for young women from diverse backgrounds.

Furthermore, the research of Rennie & McClafferty in 1995, which looked at visits to Science Centers, museums, aquariums and zoos to promote learning science, emphasizes the role that Science Centers have in enhancing science learning and changing attitudes towards science. They found that visiting interactive Science Centers offers valuable motivational opportunities for students, but noted several factors that influence the amount and nature of cognitive learning, including familiarity with the setting, prior knowledge, the level of cognitive thinking required, the structure of the visit, cues for learning, and social aspects. (Rennie & McClafferty, 1995)

In summary, the personal impact of Science Centers is multifaceted, affecting not only knowledge acquisition but also personal development, career choices, and attitudes toward science. These centers provide unique, immersive, and interactive learning environments that profoundly influence visitors' personal enjoyment, career direction, and professional expertise, particularly in STEM fields (McCreedy & Dierking, 2013).

Societal and Economical Impacts of Science Centers. Science centers, as hubs of knowledge and learning, have long played a pivotal role in shaping the societal fabric of communities. These institutions go beyond being mere venues for scientific exploration; they act as drivers for social development, community engagement, and urban regeneration.

One of the key societal impacts of Science Centers is their role in community engagement. As centers of learning and cultural activity, they attract a diverse range of visitors, fostering a sense of community and shared experience. This inclusivity is critical in building social capital, as people from different backgrounds and ages come together to learn and explore. Emily Dawson investigated the reasons behind exclusion and nonparticipation in Science Centers and museums. It focused on the experiences of individuals from disadvantaged social backgrounds, examining their perceptions before, during, and after visiting such institutions. The study revealed that these individuals often avoid visiting Science Centers and museums due to preconceived notions, expectations, and logistical challenges. It highlighted the importance of creating more inclusive science learning environments that cater to diverse ethnicities, income levels, and residential areas, acknowledging the unequal access to science and technology among different publics. (Dawson, 2018) The study emphasized the need for Science Centers and museums to adopt socially inclusive practices, requiring a conscious effort to become organizations capable of self-reflection and identifying potential unintentional biases or barriers.

In addition, Science Centers play a significant role as cultural agents in the economic development of their cities and countries, particularly through job creation and supporting additional employment in the community. In the broader context of arts organizations in the USA, which share similarities with Science Centers, these institutions support 4.85 million full-time equivalent jobs, generate $89.4 billion USD in household income, and contribute $24.4 million USD in total government revenue at various levels (Groves, 2005). A case study from South West England, further exemplifies the multiplier effect, demonstrating that every £1 output from museums results in an additional £0.74 output in other industries within the region. This activity translates to the support of an additional 0.43 jobs elsewhere in the region for each full-time equivalent job in museums, with museum-related tourist spending amounting to £27.5 million. This spending supports around 680 full-time equivalent jobs and contributes approximately £13.5 million to the region's Gross Domestic Product (Groves, 2005). These statistics underscore the substantial role that Science Centers and museums play in job creation and economic stimulation within their communities.

Figure 4. Museum Staff

Note: *From Careers at the Natural History Museum (https://nhm.org/careers-our-museums/careers-natural-history-museum)*

While employment creation and income from admissions are commonly cited as primary economic contributions, these aspects offer only a partial view of their impact on economic development. For instance, Science Centers and museums can significantly boost tourism. (Costanzo, 2022) The introduction of new Science Centers and museums offers an opportunity to form partnerships with local tourist offices and other tourist attractions. Furthermore, the creation of multi-access cards or passes at a local or regional level can strengthen a network of services, including cultural venues, gastronomy enterprises, or bookstores, providing varied benefits or discounts. This approach not only enhances the visitor experience but also supports a broader economic ecosystem. (Costanzo, 2022)

Science centers also play a vital role in urban regeneration. By attracting visitors, they contribute to the economic vitality of their surrounding areas. Science centers often serve as anchor institutions in urban regeneration projects, driving economic growth and facilitating comprehensive community development (Groves, 2005). They not only bring foot traffic to downtown areas but also stimulate investment and development in their vicinity. A prime example of this is Heureka, a science museum in Vantaa, Finland. This museum was built on a brownfield site and was deemed a piece of derelict land. The site after Heureka was built, became a park. This attracted the National Board of Forests and the Central Criminal Police of Finland to move their headquarters to the area. This sparked a major urban development in the area, creating housing and office space projects. (Persson P.-E. , 2015) The presence of Science Centers can enhance the attractiveness of neighborhoods, making them a more desirable place to live, work, and visit. This, in turn, can lead to increased property values, more businesses opening in the area, and greater overall economic activity. As a result, Science Centers can be powerful tools in revitalizing urban spaces, contributing to the economic health and vibrancy of cities.

Figure 5. Ariel Image of Heureka Science Center's Campus

Note: *From Heureka Science Center, (https://www.heureka.fi/)*

In confronting global challenges like climate change and environmental degradation, Science Centers play a pivotal role in public education about environmental issues and sustainability. Their interactive exhibits and educational programs not only inform but also raise awareness of the importance of environmental stewardship and sustainable practices. This educational focus is crucial in cultivating a society that values and participates actively in environmental conservation. Many Science Centers have stepped up as advocates for environmental issues, organizing events, workshops, and discussions centered on sustainability and climate action. By engaging the public in these critical conversations, they contribute to fostering a society that is more environmentally aware and responsible.

Science centers and museums have embraced the Sustainable Development Goals (SDGs) to address contemporary global challenges. These institutions are actively involved in creating programs and experiences that highlight crucial issues such as climate change, the impact of human activities on the ocean, and health and well-being. By doing so, they catalyze meaningful participation and encourage action towards these common goals. (Costanzo, 2022) The complexity of these global issues necessitates scientifically reliable information and social participation, aspects that Science Centers and museums are uniquely positioned to foster. For example, the Science Museum in London developed an exhibition called 'Our Future Planet' during the 26th UN Climate Change Conference of the Parties, which engaged visitors in the fight against climate change. The exhibition focuses on technologies to remove carbon dioxide from the atmosphere and showcases nature-based solutions to trap carbon emissions. (Science Museum - Kensington, 2021)

Beyond their economic impact, the educational and cultural resources provided by Science Ccenters contribute to the social and economic vitality of communities, enriching the lives of residents and visitors alike (Groves, 2005). They offer unique learning experiences and foster a sense of community, playing a crucial role in creating a stimulating and dynamic urban environment. In doing so, Science Centers not only contribute to the physical development of communities but also play a significant role in their social and cultural enrichment, underlining their importance as multifaceted institutions within urban landscapes (Groves, 2005).

Political Impacts of Science Centers. In the evolving landscape of the twenty-first century, Science Centers and museums have emerged as crucial platforms for educating the public on complex and often controversial topics. These institutions have transcended their traditional roles, becoming arenas for civil engagement and societal discourse. The Bloomfield Science Museum in Jerusalem, through its Peace Labyrinth exhibition, serves as a prime example of how Science Centers can engage visitors in nuanced discussions, fostering understanding and dialogue on sensitive issues. **(ASTC - Dimensions, 2013)**

Figure 6. Peace Labyrinth Exhibit

Note: *From Peace Labyrinth – Science Museum, The Jerusalem Foundation (https://jerusalemfoundation.org/old-project/peace-labyrinth-science-museum/)*

As the human population continues to expand rapidly in the twenty-first century, there is an increasing focus on a wide range of environmental issues. Ecotourism, already the fastest-growing sector within the world's largest industry—tourism—is a key example of this trend. (Cater & Lowman, 1994) In this context, Science Centers are presented with a significant opportunity, largely untapped, to enable individuals to actively engage in the critical discourse surrounding scientific and technological issues. The potential impact on public policy debates could be transformative if the perspectives of the over one hundred million annual visitors to Science Centers in the United States were to be collected and communicated to news media and government bodies. (Koster, 1999) This could revolutionize how public policy is shaped and informed by citizen input on critical scientific and environmental matters.

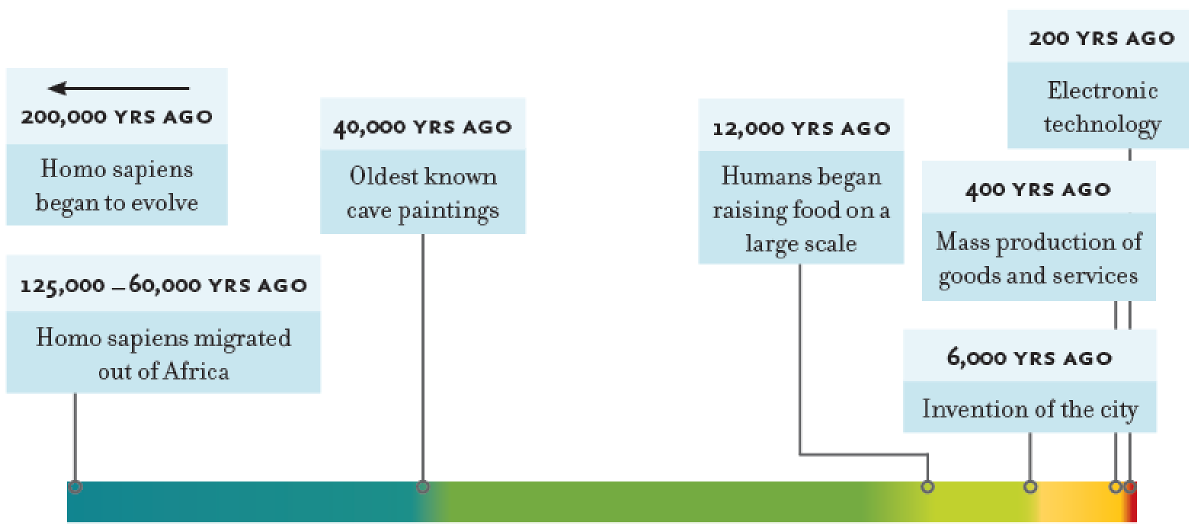
Elizabeth Stage from the Lawrence Hall of Science at the University of California, Berkeley, emphasizes the importance of presenting scientifically accurate information on controversial topics like stem cells, climate change, and evolution. This allows visitors to form their own opinions based on evidence, fostering critical thinking and informed decision-making. Such an approach not only informs but also encourages critical thinking and informed decision-making among visitors. Colin Johnson, an ASTC Fellow Award recipient, stresses the significance of sharing genuine scientific debates and disagreements, which is crucial in the journey from information to knowledge. Colin advises against a "balanced" approach that equates scientifically unsupported views, such as creationism, with well-established scientific theories like evolution. Sigrid Falla, director of research and development at Maloka Museum in Bogota, Colombia, underlines the role of Science Centers in helping citizens understand the relationship between science, technology, and societal issues. By developing exhibitions on controversial topics, Science Centers empower people to make personal decisions and engage in political scenarios where science plays a crucial role. (ASTC - Dimensions, 2013) Martin Weiss from the New York Hall of Science advocates for Science Centers to confront attacks on scientific integrity by presenting the science under scrutiny. He believes that Science Centers should take a proactive role in educating the public on controversial issues, thus fulfilling a key aspect of their mission. Francisco J. Franco del Amo, of Aquarium Finisterrae in Spain relates Science Centers to village cafés, where open and frank discussions on scientific matters can take place, thereby making science accessible and relatable to the public.

In summary, Science Centers and museums hold a significant responsibility in developing and hosting exhibitions on controversial topics. They play a pivotal role in cultivating an informed society that can thoughtfully engage with complex scientific issues. By accurately presenting scientific information and fostering public discourse, these institutions not only contribute to cultural change but also empower citizens to make informed decisions, thereby enhancing the societal and political understanding of science and technology.

Biophilia

Biophilia, a term popularized by the biologist Edward O. Wilson, refers to the inherent human inclination to affiliate with nature. (Wilson, 1986) This concept is rooted in the idea that humans possess an innate tendency to seek connections with other forms of life and nature as a whole. Wilson's hypothesis suggests that this deep-seated connection is a result of our evolutionary history; for most of human existence, a close relationship with the natural world was necessary for survival.

Figure 7. Human Evolution Timeline



Note: *From The Practice of Biophilic Design, By S. Kellert & E. Calabrese*

This connection encompasses an affinity for natural landscapes, a fascination with other living organisms, and an innate preference for natural over artificial environments. Biophilia is not just about an appreciation of nature's beauty; it's deeply intertwined with our psychological well-being, physical health, and fundamental human fulfillment.

While our inherent affinity for nature, as described by Wilson (1986), remains an essential part of our being. The study by Arne Öhman in 1986 exemplifies this complexity, showcasing our instinctive aversion to ancient natural threats like snakes and spiders, in contrast to our more subdued reactions to modern dangers such as firearms and electrical hazards (Öhman, 1986). These findings illustrate a pivot in our instinctual responses—a vestigial remnant of a time when such reactions were crucial for survival, now diminishing in the face of urban life's artificial constructs. As our built environments continue to grow, these ingrained biophilic tendencies risk atrophy, signaling a need to consciously integrate natural elements into our increasingly urban world to maintain the balance within our evolutionary psyche.

Addressing this evolutionary divergence, urban planners and designers are called to action. The challenge is to weave biophilic elements into the fabric of urban living, to counteract the fading of our primal instincts with spaces that resonate with our need for nature. Through the creation of parks, green rooftops, and buildings infused with living plants and natural light, we can nurture the biophilic connection that supports our mental and physical health. By fostering environments rich with natural elements, we not only pay homage to our ancestral past but also cater to our contemporary needs, ensuring that the essence of biophilia thrives alongside the evolution of urban landscapes.

Biophilic Design

Biophilic design aims to craft environments that serve as a suitable habitat for humans, considering their biological needs, within contemporary constructed spaces. This design approach promotes cognitive performance, reduces stress, and increases overall wellness (Kellert & Calabrese, 2015) (Browning, Ryan, & Clancy, 2014).

Figure 8. Biophilic Design

Note: *From Biophilia: Bringing Nature into Interior Design, ArchDaily, By Hirouyki Oki (https://www.archdaily.com/935258/biophilia-bringing-nature-into-interior-design)*

Three Categories of Biophilic Design. This design approach promotes cognitive performance, reduces stress, and increases overall wellness **(Kellert & Calabrese, 2015) (Browning, Ryan, & Clancy, 2014)**. By structuring this design approach into 3 categories, this creates a clear framework on how to manage the integration of biophilic design strategies into man-made environments. These 3 categories are: Nature in the Space, Natural Analogues, and Nature of the Space **(Browning, Ryan, & Clancy, 2014)**. Within these three categories of biophilic design, there are a total of 14 distinct patterns that define each category.

Table 1. 14 Patterns of Biophilic Design

Nature in the Space Patterns	Natural Analogue Patterns	Nature of the Space Patterns
1. Visual Connection with Nature	8. Biomorphic Forms & Patterns	11. Prospect
2. Non-Visual Connection with Nature	9. Material Connection	12. Refuge
3. Non-Rhythmic Sensory Stimuli	10. Complexity & Order	13. Mystery
4. Thermal & Airflow Variability		14. Risk/Peril
5. Presence of Water		
6. Dynamic & Diffuse Light		
7. Connection with Natural Systems		

(Browning, Ryan, & Clancy, 2014)

Nature in the Space. Nature in the Space pertains to the tangible and transient incorporation of natural elements within a given area. This encompasses flora, fauna, and water features, as well as sensory experiences like airflow, sounds, and aromas from the environment. Typical instances are indoor plants, gardens, feeders for birds, gardens designed for butterflies, water installations, fountains, fish tanks, and landscaped courtyards, along with living walls or green rooftops. The most profound experiences of Nature in the Space arise from forging significant, hands-on connections with these elements, especially those that offer variety, motion, and appeal to multiple senses ***(Browning, Ryan, & Clancy, 2014).*** Within the category of Nature in the Space there are seven design patterns, they are:

1. Visual Connection with Nature: A view to elements of nature, living systems and natural processes.

2. Non-Visual Connection with Nature: Auditory, haptic, olfactory, or gustatory stimuli that engender a deliberate and positive reference to nature, living systems or natural processes.
3. Non-Rhythmic Sensory Stimuli: Stochastic and ephemeral connections with nature that may be analyzed statistically but may not be predicted precisely.
4. Thermal & Airflow Variability: Subtle changes in air temperature, relative humidity, airflow across the skin, and surface temperatures that mimic natural environments.
5. Presence of Water: A condition that enhances the experience of a place through the seeing, hearing or touching of water.
6. Dynamic & Diffuse Light: Leveraging varying intensities of light and shadow that change over time to create conditions that occur in nature.
7. Connection with Natural Systems: Awareness of natural processes, especially seasonal and temporal changes characteristic of a healthy ecosystem.

(Browning, Ryan, & Clancy, 2014).

Figure 9. Nature of the Space

Note: *From Valentina A/Flickr (https://www.flickr.com/)*

Natural Analogues. Natural analogues in biophilic design encapsulate the concept of nature's representation through non-living and abstract means within built environments. This aspect of design includes various elements that are inspired by the natural world, such as art, decorations, furnishings, and textiles that feature designs and patterns echoing nature's aesthetics. These features range from ornamental details that mimic shells or leaves to furniture with organic shapes, and even to materials like wood or granite that, although processed or altered, maintain a symbolic connection to their natural origins ***(Browning, Ryan, & Clancy, 2014).*** Examples include wallpapers with leaf patterns, textiles with animal print designs, and architectural structures with flowing lines reminiscent of natural landscapes. These elements, while not directly sourced from nature, are crafted to replicate nature's textures and forms, fostering a subconscious bond with the natural world in spaces where living nature is absent. By embedding spaces with these reflections of the natural environment, natural analogues play a crucial role in enhancing well-being and tranquility. They effectively bridge the divide between contemporary human living spaces and the ancient natural world, providing rich, organized, and sometimes evolving experiences that resonate with our innate affinity for nature. Natural Analogues include 3 biophilic design patterns, they are: Biomorphic Forms & Patterns, Material connection with Nature, and Complexity & Order ***(Browning, Ryan, & Clancy, 2014).*** Within the category of Natural Analogues, there are seven design patterns, they are:

1. Biomorphic Forms & Patterns. Symbolic references to contoured, patterned, textured or numerical arrangements that persist in nature.
2. Material Connection with Nature. Materials and elements from nature that, through minimal processing, reflect the local ecology or geology and create a distinct sense of place.
3. Complexity & Order. Rich sensory information that adheres to a spatial hierarchy similar to those encountered in nature.

Figure 10. Natural Analogues

Note: *An example of a natural analogue is leaf patterned wallpaper, From CocoMurals (https://cocomurals.com/flower-wallpaper/leaf-wallpaper/)*

Nature of the space. Nature of the Space in biophilic design is centered on the natural organization and perception of spatial environments. This concept taps into our basic and learned instincts to look beyond what's immediately visible, drawing us towards the allure of the slightly risky or unknown, and engaging us with spaces that reveal themselves gradually or hide certain elements, yet still maintain a sense of safety ***(Browning, Ryan, & Clancy, 2014).*** It involves designing spaces that mirror the diverse spatial qualities of nature, encompassing varying scales, intricacies, and sensory experiences. This includes crafting areas that provide broad vistas or captivating hidden nooks, akin to vast open landscapes or secluded forest alcoves. Additionally, it entails creating environments that skillfully balance the thrilling aspects of nature with safety, much like the exhilarating yet cautious experience of standing on a cliff's edge.

Figure 11. Nature of the Space

Note: *The stepping stones at the Fort Worth Water Garden, From JayRaz/Flikr*

The objective of this design approach is to elicit the emotions and experiences commonly felt in natural settings—such as curiosity, the thrill of discovery, and a sense of refuge. By emulating nature's way of structuring and revealing itself, Nature of the Space aims to deepen our connection with our surroundings, enhancing the way we interact and experience spaces, and seamlessly integrating elements of Nature in the Space and Natural Analogues into these environments. Within the category of Nature of the Space, there are four design patterns, they are:

1. Prospect: An unimpeded view over a distance, for surveillance and planning.
2. Refuge: A place for withdrawal from environmental conditions or the main flow of activity, in which the individual is protected from behind and overhead.

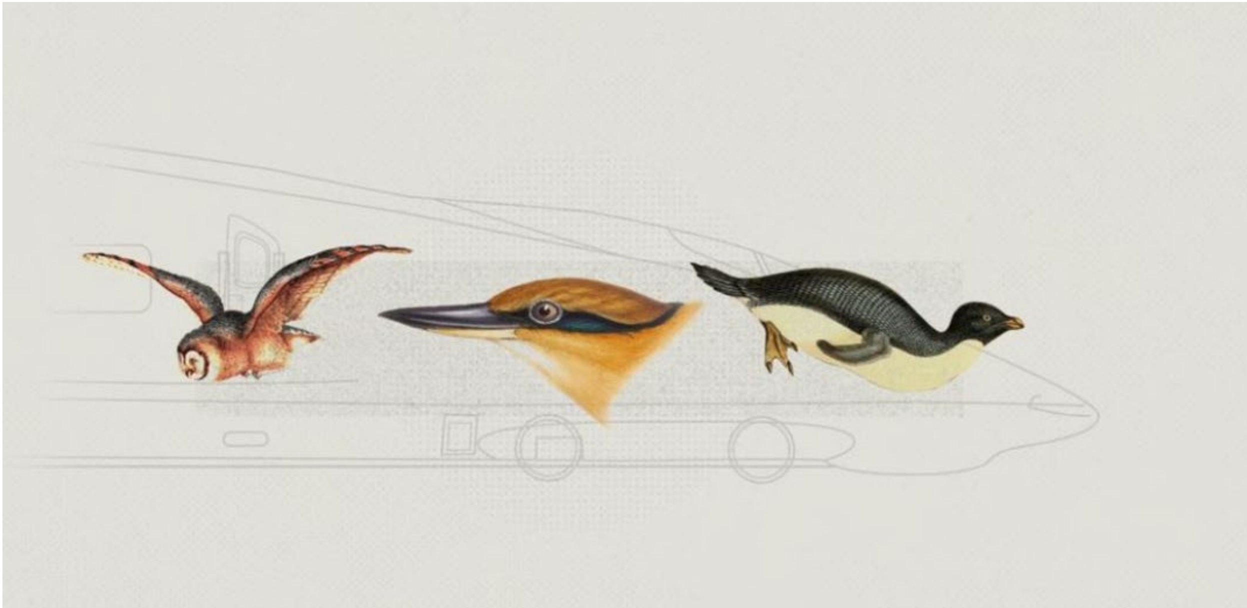
3. Mystery: The promise of more information, achieved through partially obscured views or other sensory devices that entice the individual to travel deeper into the environment.
4. Risk/Peril: An identifiable threat coupled with a reliable safeguard.

Biomimicry

Biomimicry is the innovative practice of observing and emulating patterns, forms, and strategies found in nature to address complex human challenges and needs (Kellert & Calabrese, 2015). It is a design philosophy that draws inspiration from the efficiency and adaptability of natural processes and systems. This approach includes adopting ideas from the natural world.

An example of biomimicry is the design of the Shinkansen bullet train that travels at high speeds throughout Japan. When the train was first designed it would cause pressure to build inside of the tunnels, creating a “tunnel boom” when exiting. This boom could be heard from 400 meters away and was a problem for nearby residents (Kobayashi, 2005). The challenge was to reduce this noise without slowing the train down. The team of engineers looked to nature to solve this problem. The new train design was inspired by three different types of birds in various parts of the train. The Adelie Penguin, which has a smooth body that allows it to swim and slide with ease, inspired the shape of the base on the pantograph. This piece of the train connects the train to the electrical wires running above. The design of the pantograph itself was inspired by the separation and curvature of the owl’s feathers that silently cut through the air. Finally, the nose piece of the train was inspired by the shape of the kingfisher’s beak shape (Haubursin, 2017). The kingfisher’s beak allows it to dive into water without creating a splash. By implementing these three designs into the new train, the train not only stayed under the 70-decibel limit, but also became 10% faster, and used 15% less electricity (Kobayashi, 2005).

Figure 12. Shinkansen Bullet Train Inspiration



Note: *The Owl, Kingfisher, and Adelie Penguin inspired the re-design of the Shinkansen bullet train in 1997. From The world is poorly designed. But copying nature helps, by C. Haubursin, 2017, Vox, 99% Invisible (https://www.vox.com/videos/2017/11/9/16628106/biomimicry-design-nature)*

Biomimetic principles have been implemented in the architectural context as well. Some examples of biomimetic design in architecture can be seen in the Eastgate Centre in Harare, Zimbabwe, which mimics the natural cooling mechanisms of termite mounds. The building uses a passive cooling system that regulates temperature without conventional air conditioning, significantly reducing energy consumption (Learn Biomimicry, 2023). Another example is the Gherkin in London, designed by Norman Foster, inspired by the Venus Flower Basket Sponge. Its unique lattice structure not only provides strength and stability but also allows for efficient air circulation, reducing the need for artificial heating and cooling (Nkandu & Alibaba, 2018).

Figure 13. Gherkin Biomimetic Inspiration

Note: *Gherkin in London inspired by the Venus Flower Basket Sponge, From (https://respiratorysystemjjd.weebly.com/venus-flower-basket-sponge-euplectella-aspergillum.html) & snaves/steemit*

Additionally, the Beijing National Stadium, known as the Bird's Nest, reflects the intricacy and interwoven structure of a bird's nest, using a complex steel framework to create an aesthetic that is both functional and visually striking. These buildings not only stand as testaments to modern architectural ingenuity but also showcase how nature's designs can be harnessed to create sustainable, efficient, and visually captivating structures.

Figure 14. Beijing National Stadium Biomimetic Inspiration

Note: *The Beijing National Stadium inspired by the interweaving design of a bird's nest, from Pinterest (https://www.pinterest.ie/pin/20407004539537911/)*

By harnessing these attributes from the natural world, biomimicry not only yields practical solutions and technological advancements but also fosters sustainability by aligning human-made solutions with the environmentally sound principles of nature's design.

Red River Valley Region

Overview. The Red River Valley's history is a tapestry of natural and human influences. The valley, initially shaped by Paleogeographic Lake Agassiz, has served as a crucial habitat and cultural area for indigenous cultures such as the Ojibwe and Métis. Its transformation by early Scottish settlers through the construction of drainage ditches to its present-day status as a fertile agricultural region highlights the interaction between natural forces and human endeavor. The river itself, with its gentle flow from the Red River Valley to Lake Winnipeg, has been a significant factor in the region's development, though its tendency to flood has posed challenges in recent decades **(NWF, 2023) (Redekop, 2020)**.

Figure 15. Red River Valley Region Map

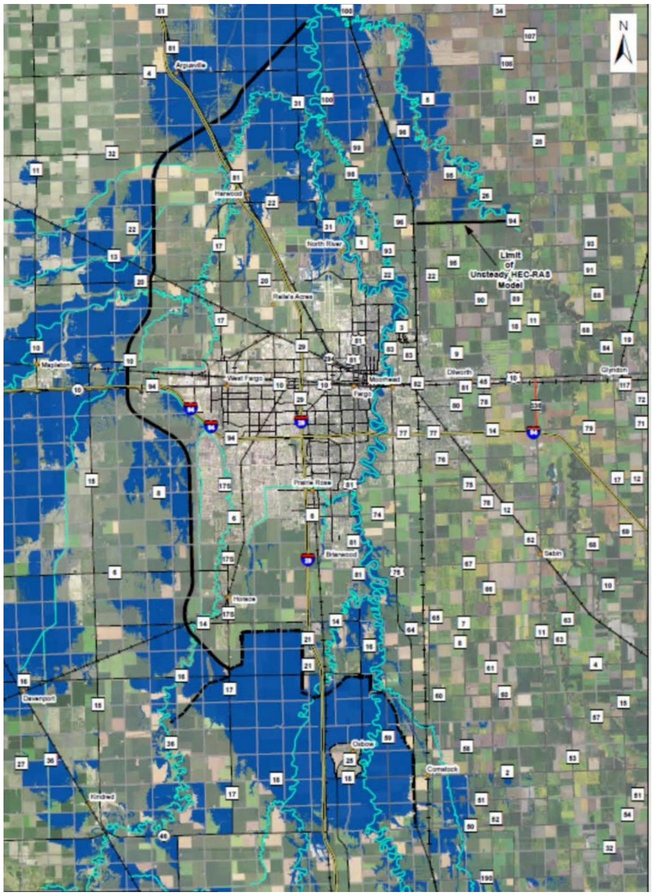
Note: *From Karl Musser (https://commons.wikimedia.org/wiki/File:Redrivernorthmap.png), via Wikimedia Commons*

Agriculture Background. The Red River Valley boasts some of the world's most fertile farmland, renowned for its nutrient-rich soil. This exceptional fertility is attributed to two key factors: firstly, the glaciers that once moved down from Canada deposited fertile soil in the area; secondly, the remnants of Lake Agassiz contributed a significant amount of organic matter, further enriching the soil. This organic richness makes the soil ideal for agriculture, enabling the growth of a variety of crops. As a result, the Red River Valley is often referred to as "The Breadbasket of the World," a testament to its prolific agricultural output. Key crops in this region include sugar beets, potatoes, corn, and wheat, underscoring the valley's vital role in global food production. This agricultural bounty, combined with its historical and geographical significance, highlights the Red River Valley's importance in both the local and global context **(North Dakota Studies, 2020).**

Flooding. Fargo in North Dakota and Moorhead in Minnesota have consistently faced the threat of flooding from the Red River. In recent times, these floods have become not only more frequent but also increasingly severe with the effects of climate change. The spring of 1997 witnessed a particularly devastating flood, inflicting damages worth $3.5 billion and necessitating the temporary evacuation of towns and cities along the border **(NWF, 2023).** Even more dramatically, in 2009, the river surged to its highest recorded level, peaking at 40.82 feet (12.44 meters) **(NWF, 2023).** As a consequence of these recurring floods, the communities in Fargo and Moorhead are now compelled to allocate over $195 million every year to address flood-related damages **(NWF, 2023).** This situation highlights the ongoing challenges these communities face in managing and mitigating the impact of the Red River's unpredictable and often destructive behavior.

To combat the frequent and severe flooding in the Red River Valley, particularly impacting Fargo, North Dakota, and Moorhead, Minnesota, flood mitigation strategies have been implemented, including levees, floodwalls, and improved emergency protocols. A cornerstone of these efforts is the Fargo-Moorhead Area Diversion Project, a significant engineering undertaking designed to redirect excess floodwaters away from the metropolitan area. This project, which involves constructing a diversion channel and related infrastructure, aims to significantly lessen the impact of flooding, safeguarding lives, property, and economic stability. (Metro Flood Diversion Authority, 2022). Representing a collaboration between various government entities and communities, this project is a proactive measure against the Red River's unpredictable flooding, offering a long-term solution to a historically challenging issue. The project is expected to be completed in 2027, which will provide the community with permanent flood protection.

Figure 16. Map of Fargo/Moorhead Diversion



Note: *the black line represents the diversion path, and the dark blue represents FEMA's 100-year flood zone estimated change after the project's completion. From Metro Flood Diversion Authority (https://fmdiversion.gov/land-management/maps/)*

While the Fargo-Moorhead Area Diversion Project is a significant step in mitigating flood risks in the Red River Valley, it is not without its drawbacks, particularly concerning its impact on the Oxbow area, located south of the metro area. This project, designed to divert floodwaters away from Fargo and Moorhead, ironically increases the potential for flooding in Oxbow (The Dickinson Press, 2018). As a direct response to this heightened risk, Oxbow is taking a defensive approach by constructing a massive levee. This levee, designed to encircle the entire town, is a necessary measure to protect Oxbow from the amplified flood waters expected each spring due to the diversion project. This situation highlights the complex balance between large-scale flood protection and its localized, sometimes adverse, impacts on neighboring communities.

Ecology. The Red River region, known for its diverse and rich ecology, is home to a wide array of natural vegetation and wildlife. The predominant grasses in the area include species like big bluestem, little bluestem, switchgrass, Indiangrass, prairie dropseed, slender wheatgrass, porcupine grass, mat muhly, fescue sedge, meadow sedge.

Figure 17. Big Bluestem Grass

Note: *From Prairie Moon Nursery (https://www.prairiemoon.com/andropogon-gerardii-big-bluestem-prairie-moon-nursery.html)*

Additionally, an array of forbs, such as western prairie-fringed orchid, blue-eyed grass, meadow anemone, prairie cinquefoil, wild licorice, prairie blazing star, tall goldenrod, black-eyed susan, white sage.

The region is also notable for its wildlife, including a variety of species with conservation priority. Birds such as the American bittern, northern harrier, sharp-tailed grouse, and several species of sparrows and owls are significant, alongside mammals like the pygmy shrew, plains pocket mouse, and the eastern spotted skunk (North Dakota Game and Fish Dept., 2019). Moreover, the area supports reptiles and amphibians, including the Canadian toad and northern prairie skink, as well as insects like the dakota skipper and monarch butterfly.

Figure 18. Northern Prairie Skink

Note: *From Sapphosyne (own work), (https//creativecommons.org/licenses/by-sa/3.01), via Wikimedia Commons*

Other characteristic wildlife includes common birds like the mallard and American kestrel, mammals such as the coyote, white-tailed deer, and a variety of ground squirrels, along with reptiles like the common garter snake. This rich tapestry of life underscores the ecological importance of the Red River region, serving as a crucial habitat for a broad spectrum of species.

Gap Identification

How to incorporate biophilic principals into a science center environment to improve its impacts.

Project Type

The proposed typology for the Science Center in the Red River Valley region is a Geological and Ecological Center with an integrated approach to STEM education, complemented by insights into the history and culture of Fargo. This type of Science Center specializes in providing interactive, educational experiences that focus on the natural sciences, particularly geology and ecology while integrating elements of local history and culture.

Centers of this nature serve as dynamic educational platforms, offering visitors a deep dive into the geological history and ecological diversity of their specific regions. They employ a range of interactive exhibits, workshops, and outdoor learning environments to engage visitors in understanding the formation of landscapes, local biodiversity, and environmental conservation strategies. Additionally, these centers often incorporate cultural and historical exhibits, enriching the educational experience by connecting the area's natural history with human stories and developments over time. This approach not only fosters a comprehensive understanding of the region's natural and cultural heritage but also actively promotes community engagement and awareness of environmental stewardship.

Project Issues

Brownfield Site Redevelopment

Issue. The chosen site for the science center is a brownfield area, which presents challenges related to environmental degradation and the need for site remediation. Redeveloping such a site is crucial for urban renewal but involves addressing soil contamination, environmental safety, and sustainable construction practices.

Risk-based Decision Making at Contaminated Sites. In the context of addressing contamination at brownfield sites, many state programs adopt a risk-based decision-making approach. This process involves several key steps to ensure informed decisions about cleanup requirements, prioritizing human health and environmental safety.

Initial Site Characterization. The process begins with a comprehensive evaluation of the site's environmental conditions. This involves identifying both potential and existing contaminants that could pose risks to the local community and environment. The evaluation typically includes Phase I and/or Phase II environmental site assessments, as per ASTM International standards. Specifically, the ASTM E1517-13 standard aligns with the EPA’s All Appropriate Inquiries Rule for conducting Phase I assessments, focusing on thorough sampling and analysis ***(EPA, 2016)***.

Risk Assessment Process. This stage entails estimating the potential adverse effects on human health and the environment due to exposure to contaminated site elements. It includes assessing risks associated with hazardous substances present at the site and the likelihood of human and environmental exposure to these substances. Furthermore, the assessment establishes a threshold for acceptable risk levels for the potentially affected human populations ***(EPA, 2016)***.

Cleanup Planning and Execution. Following the site investigation and risk assessment, a tailored cleanup plan is developed, aligning with specific cleanup and redevelopment goals. This cleanup process is typically managed and approved by state or federal regulatory bodies. Since 2013, for projects funded by the EPA, the selection of cleanup alternatives is also informed by the anticipated risks associated with climate change ***(EPA, 2016)***.

Cleanup Process. Effectively cleaning up brownfield sites is crucial for safeguarding the public against potential exposure to harmful substances. This involves strategies for either removing or confining contaminants at the site. For instance:

- Residential Sites: Cleanups at residential locations, where children and the elderly are present, necessitate removing contaminants to levels that are safe for residential exposure.
- Industrial Sites: In factories with historical contamination, cleanup might be focused on areas where worker exposure is likely, with contaminants in less accessible areas like power generation or vehicle storage being contained rather than removed.

(EPA, 2019)

The cleanup approach is largely determined by the intended future use of the site. This influences the necessity for clean soil, the use of geotextile or capping materials, land use controls, and the need for lead or asbestos abatement. The choice of technology for cleanup depends on both the cost and the nature of the contamination. Common methods include:

- Excavation: Removing surface or subsurface contaminants and contaminated soil from the site for offsite treatment or landfill disposal, followed by refilling with clean soil.
- Tank Removal: Excavating soil contaminated with gasoline or other fuels to remove underground storage tanks and piping, followed by examination and potential removal of contaminated soils beneath the tanks.

- Capping: Installing a barrier, such as a geotextile or a layer of clean soil, between contaminants and the surface to protect cleaned areas, reduce exposure, and prevent contamination spread.
- On-Site Treatment: Injecting chemicals into the soil to break down or transform contaminants into less harmful substances. This includes techniques like solidification or stabilization to prevent contaminant migration.
- Bioremediation: Using natural or adapted microbes to consume organic contaminants. This process is actively managed by adding nutrients or oxygen-releasing chemicals to enhance microbial growth and degradation of contaminants.
- Phytoremediation: Utilizing specific plants whose root systems release substances that neutralize or stabilize contaminants, or absorb them, thereby reducing soil and water contamination over time.
- Lead and Asbestos Abatement: Removing lead and asbestos by trained, licensed contractors. This process, often regulated by environmental or public health agencies, involves the careful removal of contaminated materials using specialized methods and equipment.

(EPA, 2019)

Case Study – Station Place in Portland, Oregon. Station Place, a mixed-use development in Portland, Oregon, was constructed on a 154-acre site previously used as a rail yard and manufacturing location. The cleanup strategy for this former brownfield site employed a risk-based approach, involving soil excavation and removal. This method also integrated institutional and engineering controls to manage residual contamination in soil and groundwater.

Historically, the site functioned as a rail and switching yard from the 1890s until the 1980s and hosted a manufactured gas plant for about three decades from around 1900. The Portland Development Commission acquired it in 1987, and it served as the City of Portland's Mounted Horse Patrol facility between 1990 and 2001. Extensive site investigations were conducted to determine the contamination levels in soil and groundwater. Identified contaminants included total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAH), and metals, posing direct contact risks to workers (EPA, 2016).

The remediation process focused on removing highly contaminated soils from hot spots. Engineering measures like soil caps, vapor barriers, and venting systems were implemented to limit exposure to remaining contaminants. Additionally, institutional controls were established to prevent the use of groundwater. The risk-based cleanup approach enabled the redevelopment of different site sections in accordance with future land use plans, allowing construction to progress alongside ongoing cleanup efforts, leading to the successful development of this mixed-use project (EPA, 2016).

Figure 19. Station Place in Portland, Oregon

Note: *From Redfin (https://www.redfin.com/OR/Portland/1020-NW-9th-Ave-97209/home/26440373)*

Establishment of a Science Center in Fargo

Necessity and Context. Fargo, as a growing urban center, currently lacks a dedicated facility that can serve as a hub for science education, cultural enrichment, and community engagement. The establishment of a science center is not just a matter of adding another educational institution; it's about filling a critical void in the city's cultural and educational landscape. While a Regional Science Center exists 10 miles east, in Minnesota. This Science Center serves more as a research-based field station for biological sciences, with an interpretive exhibit on the region's wildlife **(Minnesota State University Moorhead, 2023)**.

Educational Benefits. Fargo's youth and general population would greatly benefit from the interactive learning opportunities a science center provides. Such a center can ignite curiosity in science and technology, complement formal education, and foster lifelong learning. It can be a place where school groups, families, and individuals of all ages engage with scientific concepts in a hands-on, experiential manner.

The Ontario Science Centre in Toronto is renowned for its interactive approach to science education. It offers an array of hands-on exhibits and educational programs that significantly enhance science learning for school groups and families, making complex scientific concepts accessible and engaging for all ages (Ontario Science Center).

Cultural and Community Impact. A science center can become a focal point for the community, offering not only educational exhibits but also hosting events, workshops, and community programs. It can act as a catalyst for increasing public interest in science and environmental issues, particularly relevant to the Red River Valley area.

The Museum of Science and Industry in Chicago has made a profound cultural and community impact. It hosts numerous community events and workshops, fostering a strong connection with local residents and enhancing public engagement with science and technology (MSI Chicago).

Enhancing Fargo's Economic Appeal. The science center could also contribute to Fargo's appeal as a destination for visitors and new residents. It would add a unique dimension to the city’s cultural offerings, making Fargo more attractive to tourists, potential residents, and businesses considering relocation.

The Science Museum of Minnesota in St. Paul has boosted the local economy by attracting tourists and enhancing the city's cultural landscape. Its presence has contributed to the area's appeal as a destination, drawing visitors from across the region and beyond (Science Museum of Minnesota).

Fulfilling a Regional Need. The center could also serve a wider regional role, drawing visitors from the broader Red River Valley area. It would not only benefit Fargo’s immediate community but also serve as an educational and cultural resource for the surrounding region.

The Mind Museum in Taguig, Philippines, stands as the first world-class science museum in the Philippines and is the only significant science center in the region. Catering to a diverse audience across the country, it fills a crucial educational and cultural void in a nation where such resources were previously limited. The Mind Museum's unique exhibits on various scientific disciplines, including a notable focus on environmental and natural science relevant to the Philippines, make it an essential destination for fostering scientific understanding and curiosity in the region. Its presence serves not just the immediate community but also attracts visitors from across the nation, making it a central figure in science education and appreciation in the Philippines (The Mind Museum).

METHODOLOGY

Approach

In this research, I will undertake an in-depth examination of 4 case studies, focusing on how Science Centers effectively integrate biophilic design principles to enrich the visitor experience and amplify their impact. The exploration of each case study will involve a detailed analysis of the design patterns employed both in the architectural layout of the building and within the exhibits themselves. The findings will be cataloged and presented through comprehensive charts. To synthesize these findings, a final comparative chart will be developed. This will not only delineate the specific biophilic patterns applied in each case study but also provide a streamlined means to compare and contrast the approaches of different science centers. This comparative framework aims to offer a concise yet thorough overview, enabling easy access to crucial information about the application and effectiveness of biophilic design in enhancing educational and experiential aspects of science centers.

Case Studies

Table 2. Overview of Case Studies

Project Name	Location	Year Built	Square Footage	Metro Population	Annual Visitors	Target Users	Number of Levels	Brownfield Site	Typology
ECHO Leahy Center for Lake Champlain	Burlington, Vermont	2003	25,000 Sq. Ft.	225,000	150,000	Youth	2	No	Science and Nature Museum
Children's Museum and Theatre of Maine	Portland, Maine	2021	30,000 Sq. Ft.	555,000	200,000	Youth	3	Yes	Children's Museum
California Academy of Sciences	San Francisco, California	2008	400,000 Sq. Ft.	3,328,000	1,500,000	All Ages	4	No	Natural History Museum
Heureka Science Center	Vantaa, Finland	1989	88,000 Sq. Ft.	1,500,000	285,000	All Ages	1	Yes	Science Center

Echo Leahy Center for Lake Champlain – Burlington, Vermont

Located on the waterfront of Lake Champlain, the ECHO Leahy Center in Burlington, Vermont, is a vibrant hub where science and nature converge to educate and inspire. Serving a metro area with a population of roughly 225,000, a significant one-third of Vermont's total population, the center is a focal point for ecological and cultural enlightenment (United States Census Bureau, 2020). It houses an impressive collection of over 70 species of fish, reptiles, and amphibians, alongside more than 100 interactive exhibits (ECHO Leahy Center for Lake Champlain, n.d.). These exhibits educate its visitors about the rich history, diverse ecology, and the many opportunities for stewardship within the Lake Champlain Basin (ECHO Leahy Center for Lake Champlain, n.d.).

The ECHO Leahy Center for Lake Champlain significantly contributes to education, particularly through its collaboration with the University of Vermont (UVM). A key aspect of this partnership is the shared use of laboratory space, which is located at the ECHO Leahy Center on the Burlington waterfront. This laboratory is an extension of UVM's Rubenstein School of Environment and Natural Resources and is equipped with state-of-the-art research and teaching facilities. These facilities include laboratories for studying water and sediment quality, contaminants, and aquatic biota such as fish, invertebrates, and algae (The University of Vermont).

Figure 20. ECHO Front Entrance

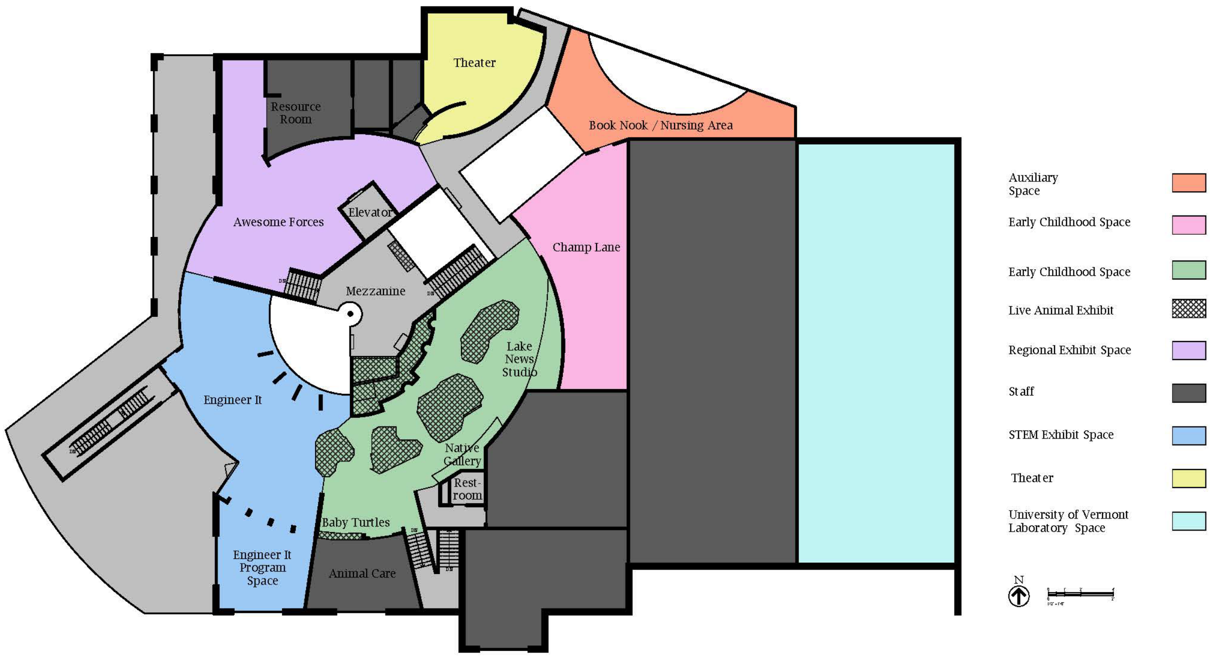
Note: *From HP Cummings Construction Company (https://www.hpcummings.com/project/echo-science-center/)*

The ECHO Leahy Center is distinguished not only by its educational offerings but also by its commitment to environmental sustainability, proudly standing as Vermont's first LEED-certified building. This distinction reflects its dedication to ecological responsibility, harmonizing with the natural beauty of its lakeside location. The center is a beacon of learning, where visitors are encouraged to actively engage with the environment. It represents a unique intersection of knowledge, discovery, and stewardship, making it a cornerstone of Burlington's community and a testament to the city's dedication to preserving and celebrating its natural surroundings.

Program Spatial Analysis. Upon entering the ECHO Leahy Center for Lake Champlain, visitors are welcomed into a spacious, open area that seamlessly integrates the museum shop, admissions desk, café, and coat rack area, creating an inviting and functional first impression. The layout leads the eye down a hallway towards the Lakeside Presentation Hall, accentuated by open clear stories overhead, enhancing the sense of openness and light. Just past the admissions desk, to the left, a stairwell ascends to the second floor, while to the right, the special exhibit space unfolds, capable of accommodating exhibits ranging from 1,700 to 2,200 square feet **(ECHO Leahy Center for Lake Champlain, n.d.)**. This area is a dynamic and flexible space, hosting a variety of rotating exhibits. A highlight on this floor is the 'Into the Lake' exhibit, which dives into the life and history of Lake Champlain and features its own stairwell leading up to the live animals exhibit on the second floor. At the far end of the main hall, the Lakeside Hall and Community Rooms are situated, versatile spaces designed to host a wide array of community events and celebrations, including weddings.

Figure 21. ECHO Leahy Center First Floor

Figure 22. ECHO Leahy Center Second Floor



Ascending the main staircase in the central hallway, visitors reach the mezzanine level, which serves as the focal point for the second floor's layout. This level features two live animal exhibits. Continuing up to the second level, guests enter the 'Awesome Forces' exhibit space, an educational area dedicated to teaching about local weather phenomena and the physics that drive them. Adjacent to this exhibit is the Resource Room, a unique interactive space where visitors can engage with researchers and inquire about Lake Champlain's intricacies. Progressing clockwise around the mezzanine, the path leads past the 3D theater and along a catwalk to the 'Champ Lane' early learning space, designed specifically for young children. Following this, the live animal exhibit space further explores the region's ecology, culture, and current environmental news. Concluding the second-floor journey is the 'Engineer It' exhibit, which presents visitors with inventive engineering challenges and interactive displays that elucidate physics principles. Additionally, the floor includes a deck offering breathtaking views over Lake Champlain, providing a serene space for reflection and appreciation of the natural beauty surrounding the center.

Analysis of Biophilic Patterns. The following tables list and describe the biophilic patterns used at the ECHO Leahy Center. Note that not all patterns are used or listed.

Table 3. Biophilic Patterns used at Echo Leahy Center for Lake Champlain

Nature in the Space	
Pattern	Description of use
Visual Connection with Nature	• Views of live animals and plants in exhibits, immerse visitors in the natural world visually • The museum's foyer features a piece of an ancient coral reef, about 500 million years old, visually connecting visitors to the geological history of Lake Champlain • The Large windows in the event space and on the second floor offer direct views of Lake Champlain and the shoreline
Non-Visual Connection with Nature	• The live butterfly exhibit provides a tactile and interactive experience, where visitors can touch and hold butterflies and plants, fostering a direct connection with nature • The Beluga Whale Dig exhibit engages children in a sensory exploration, allowing them to dig through mulch to discover bones • Sounds of trickling water from the center's aquariums and the misting rocks at the entrance create an auditory and tactile connection with natural water elements • The Steaming Lakes exhibit introduces an interactive fog-based tornado, allowing visitors to experience and manipulate airflow
Non-Rhythmic Sensory Stimuli	• The erratic flight paths and actions of butterflies create an unpredictable visual spectacle

Table 3. Biophilic Patterns used at Echo Leahy Center for Lake Champlain (continued)

Nature in the Space	
Pattern	Description of use
Presence of Water	• Aquariums offer a visual and auditory experience of water • Touch tanks provide a hands-on experience, allowing visitors to physically interact with water and marine life • The Bubble Tower, stretching from the first to the second floor, creates a captivating visual and auditory water feature • An expansive view of Lake Champlain from the center allows visitors to appreciate the vastness and beauty of the lake
Dynamic & Diffuse Light	• The Rippling Waters exhibit allows visitors to interactively create wave patterns that are then projected onto the floor below, creating a dynamic play of light and shadow that mimics natural water movements • Skylights placed throughout the center harness natural light, creating changes in brightness and shadow throughout the day
Connection with Natural Systems	• The Shaping Watersheds exhibit offers an interactive, hands-on experience where visitors can sculpt landscapes and observe virtual rain flow patterns, enhancing their understanding of natural water systems • The Flowing Streams exhibit allows visitors to pump water through a model stream system, offering hands-on learning about water dynamics and river ecology • The Freezing Water exhibit allows guests to observe the formation of ice crystals in real-time • The Steaming Lakes exhibit engages visitors with an interactive tornado made from rotating fog, demonstrating airflow and weather phenomena

Figure 23. Live Animal Exhibit at ECHO Leahy Center for Lake Champlain

Note: *From ECHOvt/tripadvisor (https://www.tripadvisor.com/Attraction_Review-g57201-d282720-Reviews-ECHO_Leahy_Center_for_Lake_Champlain-Burlington_Vermont.html#/media-atf/282720/412399993:p/?albumid=-160&type=0&category=-160)*

Figure 24. Large Ancient Coral Reef Piece

Note: *From Dave McWhorter (https://traveljournalbydave.blogspot.com/2015/12/echo-leahy-center-for-lake-champlain.html)*

Figure 25. Large Expansive Windows Overlooking Lake Champlain

Note: *From WeddingWire.com (https://www.weddingwire.com/biz/echo-leahy-center-for-lake-champlain-burlington/db98b0a097d284e0.html)*

Figure 26. Dig Pit

Note: *From winnsmash/tripadvisor (https://www.tripadvisor.com/Attraction_Review-g57201-d282720-Reviews-ECHO_Leahy_Center_for_Lake_Champlain-Burlington_Vermont.html#/media-atf/282720/267580653:p/?albumid=-160&type=0&category=-160)*

Figure 27. Fog Tornado at ECHO Leahy Center for Lake Champlain

Note: *From ECHO Leahy Center for Lake Champlain (https://www.echovermont.org/animals-exhibits/awesome-forces/)*

Figure 28. Bubble Tower at ECHO Leahy Center for Lake Champlain

Note: *From ECHO Leahy Center for Lake Champlain (https://www.echovermont.org/animals-exhibits/exhibits/)*

Figure 29. Ripple Patterns in Lighting at ECHO Leahy Center for Lake Champlain

Note: *From ECHO Leahy Center for Lake Champlain (https://www.tripadvisor.com/Attraction_Review-g57201-d282720-Reviews-ECHO_Leahy_Center_for_Lake_Champlain-Burlington_Vermont.html#/media-atf/282720/?albumid=-160&type=0&category=-160)*

Figure 30. Lilypad Sculpture Outside ECHO Leahy Center for Lake Champlain

Note: *From JNYCwriter/tripadvisor (https://www.tripadvisor.com/Attraction_Review-g57201-d282720-Reviews-ECHO_Leahy_Center_for_Lake_Champlain-Burlington_Vermont.html#/media-atf/282720/498040327:p/?albumid=-160&type=0&category=-160)*

Figure 31. Touch Pond

Note: *From ECHOvt/tripadvisor (https://www.tripadvisor.com/Attraction_Review-g57201-d282720-Reviews-ECHO_Leahy_Center_for_Lake_Champlain-Burlington_Vermont.html)*

Table 4. Natural Analogues used at Echo Leahy Center for Lake Champlain

Natural Analogues	
Pattern	Description of use
Biomorphic Forms & Patterns	• The lily pad/seaweed sculpture outside, symbolizes the center's connection to aquatic life • The railing over the main entrance is designed with a natural, rock-like form, blending the architectural elements with the natural ruggedness of the surrounding landscape • Wooden bird models suspended over the live animal exhibit not only add an artistic touch but also serve as a symbolic representation of the region's avian life • Walls throughout the center mimic natural textures that subtly remind visitors of the natural world's intricate patterns and designs
Material Connection with Nature	• The strong use of wood in its live animal exhibits, a material choice that brings a warm, organic feel to the space. This use of minimally processed wood creates a tangible connection between the exhibits and the natural environment, enhancing the sense of place and immersion in nature
Complexity & Order	• The hallway design of the live animal exhibit uses overhanging plants along the hallway to introduce a natural, organic element, while the exhibit features rounded, naturally curving shapes with strategic bump-outs that mirror the intricate yet ordered patterns found in nature, creating an environment that is both visually stimulating and navigable

Figure 32. Complexity and Order and Use of Wood in the Live Animal Exhibit's Hallway

Note: *From Mmonarque/tripadvisor (https://www.tripadvisor.com/Attraction_Review-g57201-d282720-Reviews-ECHO_Leahy_Center_for_Lake_Champlain-Burlington_Vermont.html)*

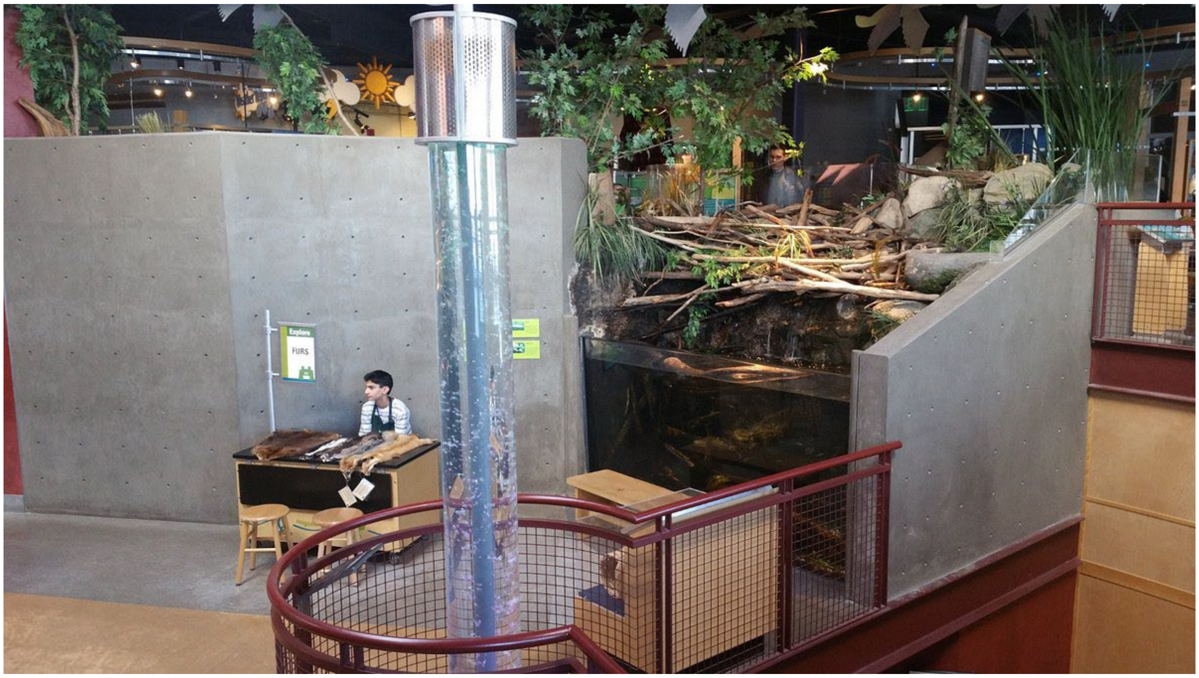
Table 5. Nature of the Space Patterns used at Echo Leahy Center for Lake Champlain

Nature of the Space	
Pattern	Description of use
Prospect	• Expansive views of Lake Champlain offer visitors a broad and uninterrupted visual connection to the natural landscape • An open floor plan that enhances the sense of space and visibility, allowing for easy observation of the surrounding environment

Table 5. Nature of the Space Patterns used at Echo Leahy Center for Lake Champlain (continued)

Nature of the Space	
Pattern	Description of use
Refuge	• Into the Lake exhibit offers a life-sized recreation of a shipwreck, allowing visitors to immerse themselves in a unique, enclosed environment. It serves as a retreat from the main flow of museum activities, providing a sense of protection and seclusion as visitors explore the history of the shipwrecks in Lake Champlain's Underwater Historic Preserve • Smaller hideouts for younger children to climb and explore in the Champ Lane Exhibit provide a space of refuge from the rest of the exhibit space
Mystery	• Into the Lake exhibit, featuring a life-sized recreation of a shipwreck, embodies the essence of mystery. The design of the exhibit entices visitors to explore further, promising more information and discovery as they journey through the wreck
Risk/Peril	• A mezzanine that overlooks the first floor, along with intriguing cutouts in the floor over the entrance area offer visitors a sense of height and exposure, simulating a thrilling experience of risk while being entirely safe • Champ Lane Early Learning Exhibit includes a tree house, bridge, and slide, which are perfect for encouraging risk-taking in a controlled and secure environment for your children

Figure 33. ECHO Leahy Center's Mezzanine Overlook



Note: *From SomethingTookish/Tripadvisor (https://www.tripadvisor.com/Attraction_Review-g57201-d282720-Reviews-ECHO_Leahy_Center_for_Lake_Champlain-Burlington_Vermont.html)*

Figure 34. Expansive Views of Lake Champlain

Note: *From Zephyr_Travel/tripadvisor (https://www.tripadvisor.com/Attraction_Review-g57201-d282720-Reviews-ECHO_Leahy_Center_for_Lake_Champlain-Burlington_Vermont.html#/media-atf/282720/341434194:p/?albumid=-160&type=0&category=-160)*

Figure 35. Shipwreck in the Into the Lake Exhibit

Note: *From helloburlingtonvt.com (https://www.helloburlingtonvt.com/blog/post/rainy-day-activities-for-families-in-burlington/)*

Figure 36. Champ Lane Hideouts

Note: *From Jim Hilker/google maps (https://www.google.com/maps/@44.4765105,-73.2210982,3a,75y,68.97h,79.59t/data=!3m8!1e1!3m6!1sAF1QipMmbcd7bT3jZuFuuAbP5jzABSZWWhFUk29w23qx!2e10!3e11!6shttps:%2F%2Flh5.googleusercontent.com%2Fp%2FAF1QipMmbcd7bT3jZuFuuAbP5jzABSZWWhFUk29w23qx%3Dw203-h100-k-no-pi-0-ya187.68372-ro0-fo100!7i10000!8i5000?hl=en&entry=ttu)*

Site. The site design is thoughtfully crafted to merge maritime interpretative exhibits with a publicly accessible boardwalk, offering a unique view of the busy waterfront. The site is designed to be not just a space but an interactive learning experience, showcasing a dynamic representation of the geological processes that shaped the Champlain Basin. Elements like water, steam, and rugged slate sourced from local shorelines are integrated into the design. The environment is further enriched with natural materials from Lake Champlain itself, such as crushed shells, fossils, sea glass, and reeds, adding depth and texture to the site's features. The dealer.com lakeside terrace and pavilion serve dual purposes: they provide a sheltered area for events and also act as a practical demonstration of environmentally friendly practices like permeable paving and rainwater harvesting. Additionally, the building's upper levels are designed to channel stormwater into a linear raingarden, illustrating sustainable water management practices. This design not only enhances the aesthetic appeal but also educates visitors on eco-friendly architectural solutions.

Figure 37. ECHO Leahy Center for Lake Champlain Site Map

Note: *(Modeled after Google Earth Pro, 2022)*

Figure 38. ECHO Leahy Center Site Features

Note: *(Left) drains that channel stormwater into a linear raingarden. (Right) Rugged slate from the regional shoreline emits steam and water, interpreting the geologic forces that created the Champlain Basin. From WHLA (https://wagnerhodgson.com/projects/echo-leahy-center-for-lake-champlain/)*

Summary. The ECHO Leahy Center for Lake Champlain stands as a remarkable embodiment of sustainable architecture and biophilic design, seamlessly integrated with its natural lakeside setting in Burlington, Vermont. Its commitment to environmental stewardship is showcased not only through its LEED-certified construction but also through its interactive exhibits that intricately blend elements of the local ecosystem, geology, and wildlife. The center's collaboration with the University of Vermont enhances its educational impact, sharing significant laboratory space for research and teaching, directly linking scientific exploration with public education. This partnership enriches the visitor experience with insights into cutting-edge environmental research. The ECHO Center skillfully employs biophilic patterns, creating a space where visitors can deeply connect with nature through tactile, visual, and educational experiences. This innovative approach not only enriches the visitor experience but also reinforces the Center's mission to foster a deeper appreciation and understanding of the natural world, setting a precedent for future ecological and educational endeavors.

Children's Museum and Theatre of Maine – Portland, Maine

The Children's Museum & Theatre of Maine, nestled in the heart of Portland, stands as a vibrant testament to the power of interactive learning and cultural enrichment. Founded in 1970 by the Junior League of Portland, the museum has evolved from its humble beginnings in Fort Williams Park to its current state-of-the-art facility (Childrens Museum & Theatre of Maine, n.d.). With a focus on science education, early childhood development, and multicultural learning, the museum has become a cornerstone of the community, offering a rich tapestry of experiences for children aged 6 months to 10 years.

In 2008, the museum celebrated a significant milestone with the merger of the Children's Theatre of Maine, a storied institution dating back to 1923 (Childrens Museum & Theatre of Maine, n.d.). This union marked a new chapter in providing immersive theatrical experiences for and by children, further enriching the museum's educational offerings. The new facility, located along the scenic Fore River and west of downtown, is a marvel of modern design, inspired by the industrial heritage of Thompson's Point. It features a 100-seat theatre, flexible exhibit spaces, and an inviting outdoor play area, all thoughtfully integrated to reflect Maine's unique cultural and natural landscape (Bruner/Cott Architects, n.d.).

The building's design is not just aesthetically pleasing but also functionally brilliant, catering to the needs of both children and adults. The spacious lobby, surrounded by floor-to-ceiling glass, floods the space with natural light, creating a seamless connection between the indoor and outdoor environments. The museum's commitment to sustainability is evident in its approach to renovating the brownfield site and employing eco-friendly practices like low-wattage LED lighting and a radiant floor in the main lobby (Bruner/Cott Architects, n.d.).

Figure 39. Children's Museum and Theatre of Maine

Note: *From The Children's Museum and Theatre of Maine (https://www.kitetails.org/outdoor-adventure)*

Brownfield Site. The Children's Museum & Theatre of Maine's recent move to Thompson's Point, a 25-acre peninsula along the Fore River in Portland, Maine, represents a significant shift from its industrial origins to a center of cultural and educational significance. Originally developed as a railroad yard in the late 1880s, Thompson's Point has undergone a remarkable transformation, beginning with a comprehensive multi-brownfield redevelopment effort in 2013 (EPA, n.d.). The museum, established in 1923 and formerly located in Portland's Art District, had outgrown its previous space. Following a successful fundraising campaign that raised over $15 million, the museum acquired a 1.12-acre property on Thompson's Point in 2017. This relocation was part of a larger initiative to revitalize the area while preserving its historical significance.

The redevelopment of the site for the museum involved extensive environmental remediation, addressing soil contaminants such as polycyclic aromatic hydrocarbons (PAHs), arsenic, and petroleum. This cleanup was supported by EPA and private funding, including a significant Brownfields cleanup grant (EPA, 2022). Emphasizing sustainable building practices, the project included pre-loading the building site with a barrier to compact the area and minimize soil removal. Additionally, stormwater storage tanks were installed to protect groundwater and manage stormwater runoff, a crucial consideration in light of increasing storm intensity due to climate change.

Figure 40. Children's Museum and Theatre of Maine Site Before

Note: *(Modeled after Google Earth Pro, 2022)*

Figure 41. Children's Museum and Theatre of Maine Site After

Note: *(Modeled after Google Earth Pro, 2022)*

Spatial Analysis. The first floor of the Children's Museum & Theatre of Maine is a vibrant, light-filled atrium, thanks to its surrounding windows that flood the space with natural light. This area is home to a child-friendly climbing wall, situated near a comfortable seating and eating area, making it a perfect spot for families to relax and engage. The first floor is primarily dedicated to the theater, a cornerstone of the museum's educational offerings. The Maddie Theater, designed specifically for young audiences, hosts generational plays and theater ensembles, fostering a unique mentorship program where actors of all ages learn from each other. The theater's programming reflects the diversity of Maine, featuring a range of performing artists and stories that resonate with the community. It is equipped with a teaching tech booth, a soundproof viewing gallery, its own dedicated lobby, and a green room and workshop backstage, making it a state-of-the-art facility tailored for young families. Additionally, the first floor extends its educational reach outdoors with exhibits like the Native Storytelling exhibit, which honors the Wabanaki people's cultural legacy in Maine. Children can also engage with hands-on learning in the outdoor sandbox and seasonal garden, enhancing their connection with nature and local history.

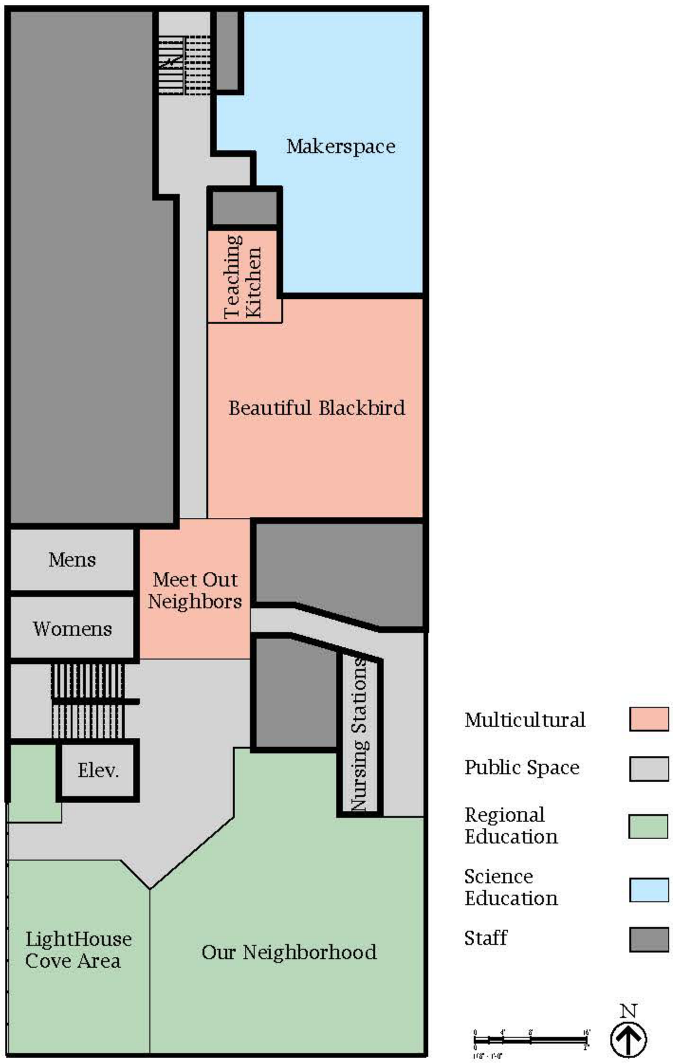
Figure 42. Children's Museum & Theatre of Maine First Floor

The second floor of the museum offers a diverse array of exhibits, with a focus on early childhood learning. Located on the south side, these exhibits are designed to engage young minds in a variety of regional themes. As visitors move along the main hallway towards the north end of the building, they encounter multicultural exhibits that celebrate the diverse cultural tapestry of the region. This floor also houses a makers space, a creative area resembling a woodshop or workshop, where children are encouraged to create and build. This interactive space not only fosters creativity but also helps develop fine motor skills and problem-solving abilities, making it a vital part of the museum's educational experience.

Figure 43. MakerSpace at Children's Museum & Theatre of Maine

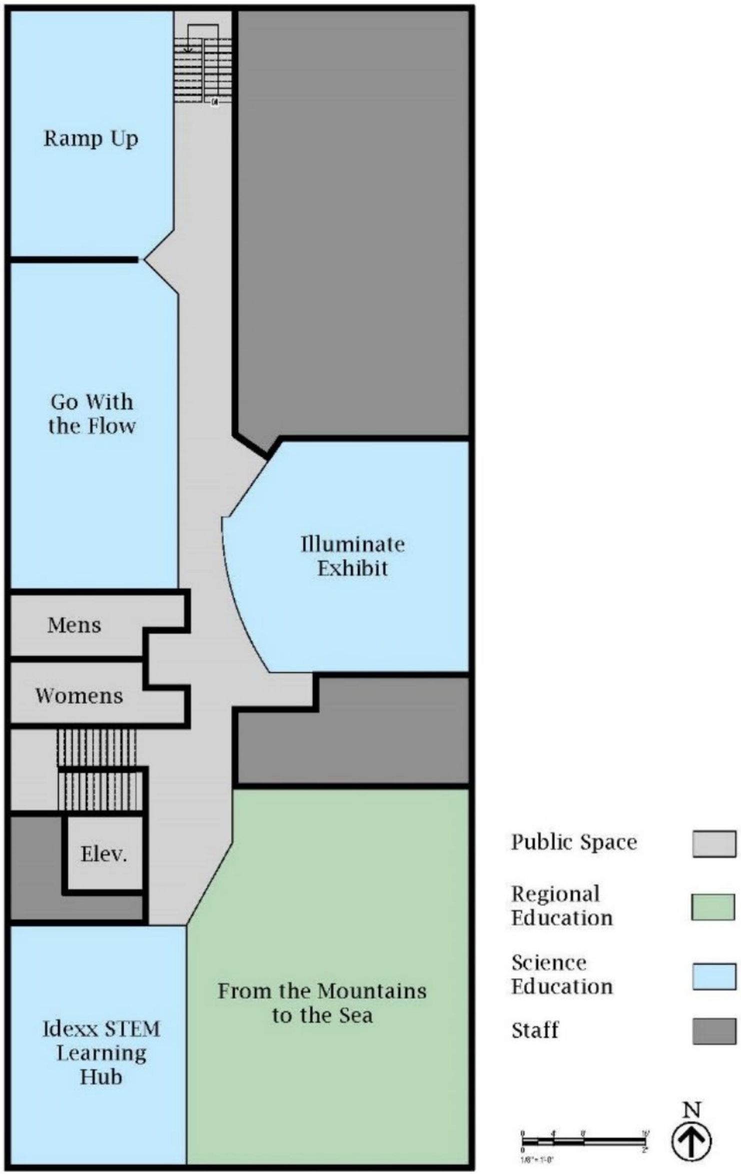
Note: *From Children's Museum & Theatre of Maine (https://www.kitetails.org/makerspace)*

Figure 44. Children's Museum & Theatre of Maine Second Floor



The third floor of the museum is dedicated to science-related education, featuring a range of exhibits that explore natural systems and regional ecology. These exhibits are designed to educate visitors about the diverse ecosystems of the region, from the mountains to the sea. The floor's layout and content are thoughtfully curated to provide an immersive learning experience, allowing visitors to explore and understand the intricate connections within natural environments.

Figure 45. Children's Museum & Theatre of Maine Third Floor



Today, the Children's Museum & Theatre of Maine continues to thrive, drawing visitors from across the region and beyond. Its dynamic programs and exhibits, coupled with enchanting theatre productions, offer a unique blend of education and entertainment. This institution is more than just a museum or theatre; it's a community hub where children and families can explore, learn, and grow together, making it a beacon of inspiration for similar institutions worldwide.

Analysis of Biophilic Patterns. The following tables list and describe the biophilic patterns used at the Children's Museum & Theatre of Maine. Note that not all patterns are used or listed.

Table 6. Biophilic Patterns used at the Children's Museum & Theatre of Maine

Nature in the Space	
Pattern	Description of use
Visual Connection with Nature	• Extensive use of windows provides panoramic views of the outside, connecting visitors to the external environment • The "From the Mountains to the Sea" exhibit features aquariums that offer a visual connection to aquatic life • The seasonal beehives and garden show the cycles of nature
Non-Visual Connection with Nature	• Sounds and tactile experiences from the aquariums and "Go With the Flow" exhibit's water tables offer a sensory connection to the element of water
Non-Rhythmic	• On the climbing wall, the irregular arrangement and coloring of the climbing platforms provide a stochastic visual experience, with no predictable pattern or rhythm • The building's exterior features a non-rhythmic pattern of blue, grey, and white paneling, creating a dynamic and unpredictable visual effect that reflects the stochastic patterns often observed in natural environments
Presence of Water	• Aquariums and Water Tables enhance the space with the visual, auditory, and tactile qualities of water
Dynamic & Diffuse Light	• In the main atrium, the climbing wall diffuses light in a vibrant manner • Interactive pieces in the "Illuminate" exhibit create reflections and patterns of light on walls and ceilings

Table 6. Biophilic Patterns used at the Children's Museum & Theatre of Maine (continued)

Nature in the Space	
Pattern	Description of use
Connection with Natural Systems	• Windows allow observation of changing weather patterns • The "From the Mountains to the Sea" exhibit educates visitors about water processes and regional geology

Figure 46. Windows at Children's Museum & Theatre of Maine

Note: *From Children's Museum & Theatre of Maine (https://www.kitetails.org/accessibility)*

Figure 47. Beehives at Children's Museum & Theatre of Maine

Note: *From Children's Museum & Theatre of Maine (https://www.kitetails.org/accessibility)*

Figure 48. Water Tables at the Children's Museum & Theatre of Maine

Note: *From The Childrens Museum & Theatre of Maine (https://www.kitetails.org/exhibit-go-with-the-flow)*

Figure 49. Illuminate Exhibit at Children's Museum & Theatre of Maine

Note: *From Children's Museum & Theatre of Maine (https://www.kitetails.org/illuminate)*

Figure 50. Curved walls inside the Children's Museum & Theatre of Maine

Note: *From Children's Museum & Theatre of Maine (https://www.kitetails.org/illuminate)*

Table 7. Natural Analogues used at the Children's Museum & Theatre of Maine

Natural Analogues	
Pattern	Description of use
Biomorphic Forms & Patterns	• The wallpaper in the "From the Mountains to the Sea" exhibit depicts local scenery, bringing natural forms indoors • The flooring in the "From the Mountains to the Sea" exhibit simulates the texture and appearance of grass
Material Connection with Nature	• The outside playground is made entirely of wood which reflects a direct material connection to nature
Complexity & Order	• Different flooring materials in exhibits guide visitors along a path or focused area

Figure 51. From the Mountains to the Sea Exhibit

Note: *From The Childrens Museum & Theatre of Maine (https://www.kitetails.org/news-blog/exhibit-feature-friday-from-the-mountains-to-the-sea-freshwater)*

Table 8. Nature of the Space Patterns used at the Children's Museum & Theatre of Maine

Nature of the Space	
Pattern	Description of use
Prospect	• Large windows on all floors provide broad, unobstructed views of Portland, Maine, offering a sense of openness and surveillance
Refuge	• There is a secluded hideout in the climbing wall for children to discover • Varied structures like cars, boats, houses, and tents offer smaller, enclosed spaces within the larger exhibit areas for exploration and retreat
Mystery	• Curved walls in exhibits limit direct views and encourages curiosity and exploration
Risk/Peril	• The climbing wall provides a safe yet thrilling experience for children

Figure 52. Climbing Wall at The Children's Museum & Theatre of Maine

Note: *From The Children's Museum & Theatre of Maine (https://www.kitetails.org/first-floor)*

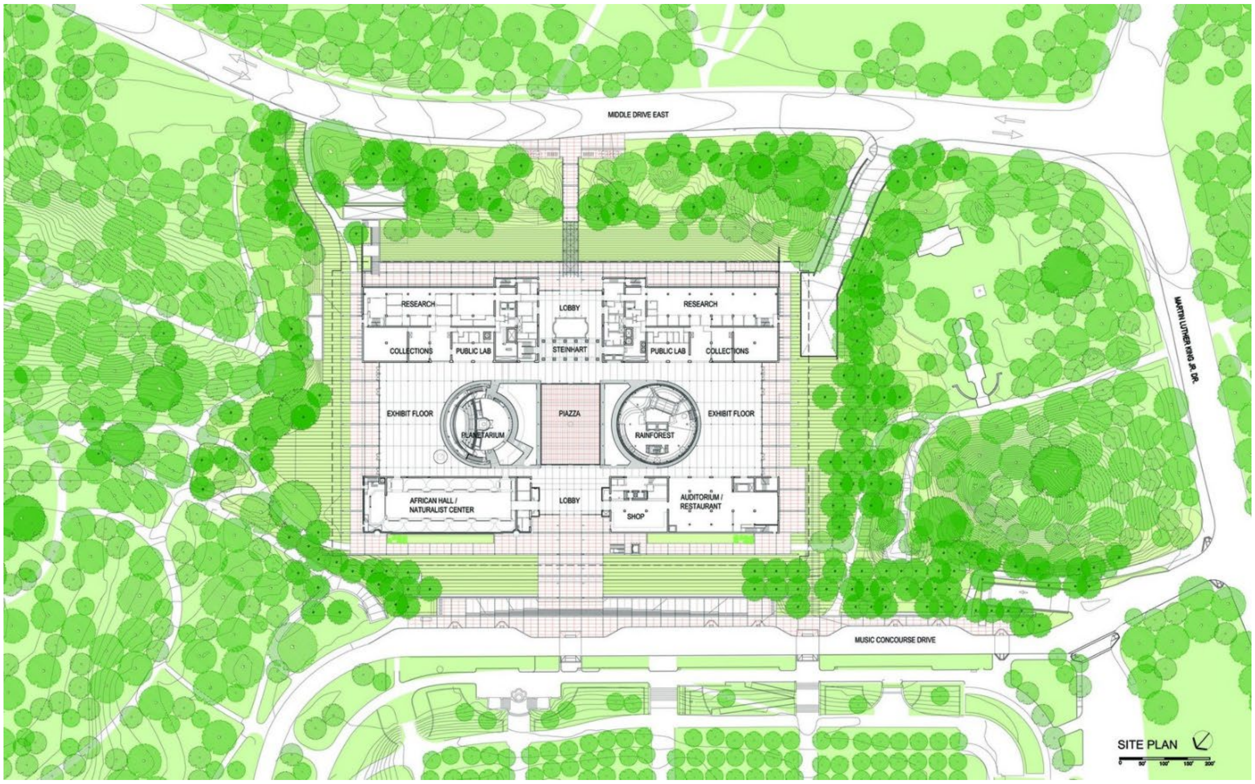
California Academy of Sciences – San Francisco, California

The California Academy of Sciences in San Francisco, reborn from the aftermath of the Loma Prieta earthquake, stands as a beacon of natural history and scientific inquiry. Established in 1853, this prestigious institution was reimagined after the earthquake necessitated the reconstruction of its original structures. Today, it is not only one of the largest museums of natural history globally, with over 26 million specimens, but also a symbol of resilience and innovation.

Figure 53. California Academy of Sciences

Note: *From Tom Fox, SWA Group, via ArchDaily.com (https://www.archdaily.com/6810/california-academy-of-sciences-renzo-piano?ad_source=search&ad_medium=projects_tab)*

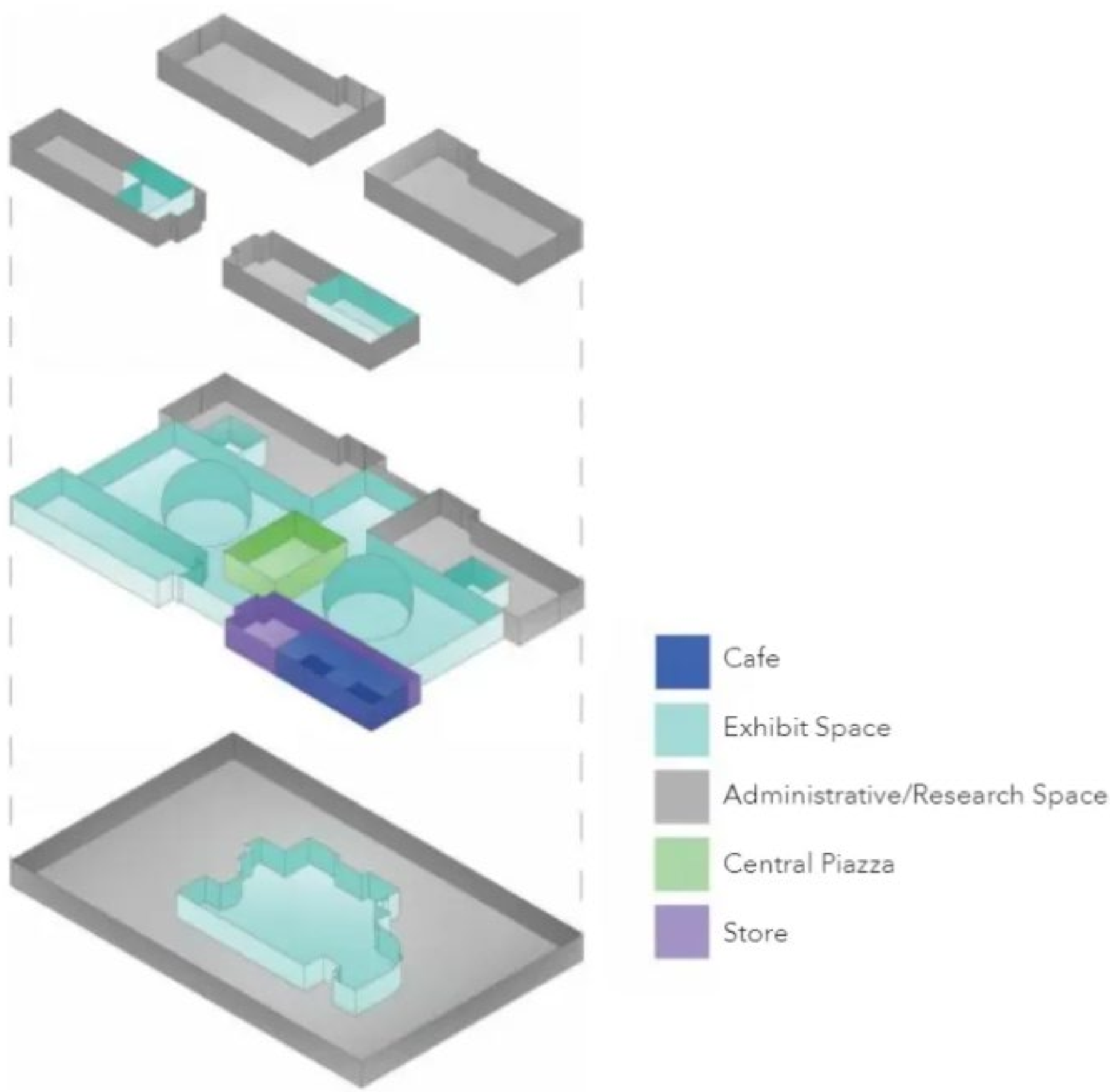
Figure 54. Site Plan of California Academy of Sciences



Note: *From Archdaily.com (https://www.archdaily.com/6810/california-academy-of-sciences-renzo-piano/5721cbbae58ece2dec000001-california-academy-of-sciences-renzo-piano-site-plan?next_project=no)*

Program and Spatial Analysis. The California Academy of Sciences skillfully intertwines public engagement with dedicated research spaces. The primary public exhibits span the ground floor, basement, and parts of the second floor, offering an immersive educational experience. The building's entrance, featuring a retail space and café, warmly welcomes visitors into this world of discovery. Administrative functions are strategically located to ensure seamless operations without intruding on the public spaces. The heart of the building is an open-plan main floor, centered around a courtyard and spheres, fostering a sense of exploration and free-flowing movement. The museum's design incorporates elements of the original structures, now remodeled with sustainable and earthquake-resistant features, including a concrete basement that anchors the aquarium section.

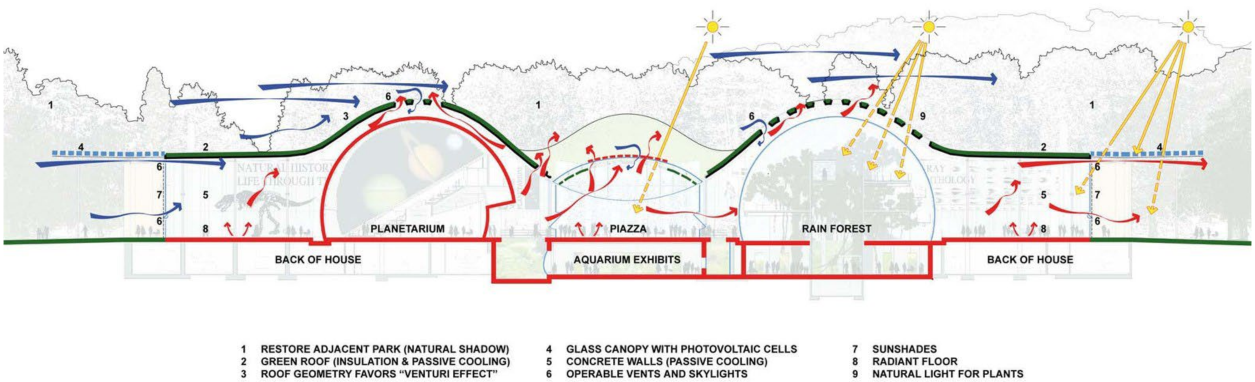
Figure 55. Exploded View of California Academy of Sciences



Note: *From Niralee Shah, via Archestudy.com (https://archestudy.com/case-study-of-california-academy-of-sciences-san-francisco-usa/)*

Architectural Analysis. The architectural design of the California Academy of Sciences, led by Renzo Piano Workshop, is a masterclass in blending nature with structural design. The building's living roof, inspired by San Francisco's iconic hills, not only enhances natural ventilation but also aids in rainwater collection. This green roof symbolically unites the new structure with the remnants of the original buildings. The roof's soil layer plays a crucial role in insulating the building and managing stormwater runoff. Surrounding the green roof, a photovoltaic overhang houses thousands of solar cells, significantly contributing to the Academy's energy requirements. The building's design optimizes natural light while controlling solar heat gain, aligning with San Francisco's temperate climate.

Figure 56. Section Cut of California Academy of Sciences



Note: *The use of natural ventilation and natural sunlight through portholes in the green roof eliminates the need for air conditioning on the main level as well as limits the amount of artificial light needed. From Archdaily.com (https://www.archdaily.com/6810/california-academy-of-sciences-renzo-piano?ad_source=search&ad_medium=projects_tab)*

Analysis of Biophilic Patterns. The following tables list and describe the biophilic patterns used at the California Academy of Sciences. Note that not all patterns are used or listed.

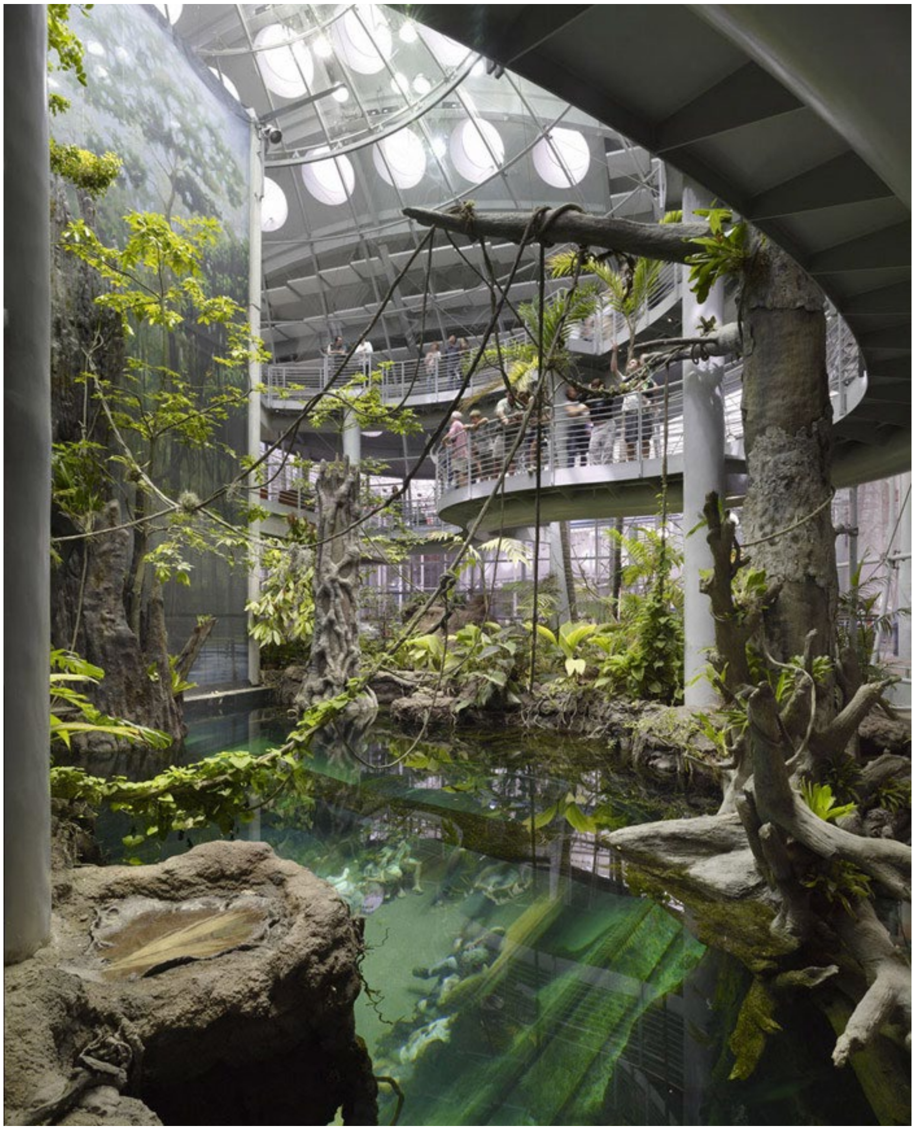
Table 9. Biophilic Patterns used at the California Academy of Sciences

Nature in the Space	
Pattern	Description of use
Visual Connection with Nature	• Live plants throughout the interior enhance the natural aesthetic and provide a direct visual connection to nature • The rainforest dome allows visitors to observe a rich array of flora and fauna, simulating an authentic rainforest environment • Live animal exhibits feature diverse animal species, offering guests a close-up view of wildlife and their natural behaviors • The living green roof is both functional and symbolic, representing a seamless integration of the building with natural elements • The use of a large glass facade offers expansive views into the surrounding park
Non-Visual Connection with Nature	• In the rainforest dome, visitors can physically interact with the environment, touching plants and feeling the flutter of butterflies, which enhances the sensory connection to nature • The sounds of birds chirping in the rainforest dome create an auditory connection with nature • The distinct smells of plant life and animals within the rainforest dome provide an olfactory experience that deepens the connection to natural processes and living systems
Non-Rhythmic Sensory Stimuli	• The erratic flight paths and actions of butterflies in the rainforest dome create an unpredictable visual spectacle • The birds' sporadic flight patterns and their potential to perch near or fly past visitors unpredictably contribute to a sensory experience that is both stochastic and engaging
Thermal Airflow	• Porthole openings in the living green roof allow subtle variations in temperature and air movement, reminiscent of breezes in natural settings

Table 9. Biophilic Patterns used at the California Academy of Sciences (continued)

Nature in the Space	
Pattern	Description of use
Presence of Water	• Aquariums and open water pools throughout the building enable visitors to observe and interact with aquatic life
Dynamic & Diffused Light	• Skylight portholes allow natural light to stream in, while trees in the rainforest dome cast moving shadows, creating a play of light and shade that changes throughout the day • Shading devices installed over large windows modulate and diffuse sunlight
Connection with Natural Systems	• The vibrant ecosystem within the rainforest dome, teeming with birds, insects, fish, and reptiles, offers visitors a direct connection to a diverse and dynamic natural system

Figure 57. Osher Rainforest

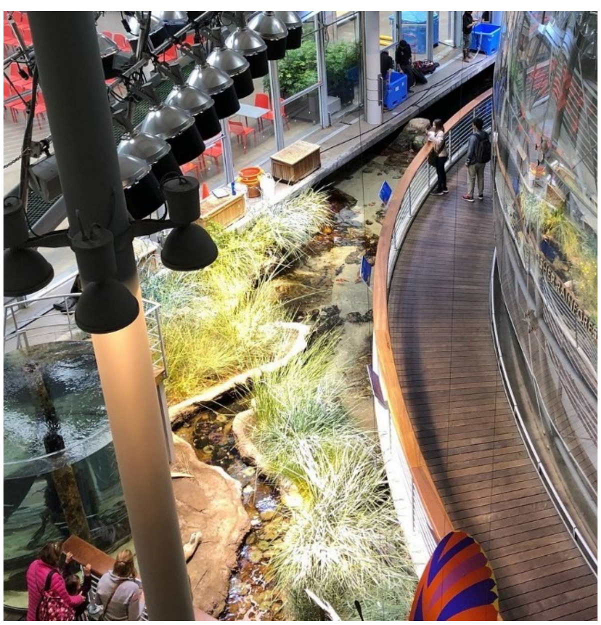


Note: *The Osher Rainforest is a dome that is four stories tall inside of the California Academy of Sciences. Inside of the dome is an ecosystem of free-flying birds and butterflies with exotic reptiles, amphibians, insects and fish. From Tim Griffith via ArchDaily.com (https://www.archdaily.com/6810/california-academy-of-sciences-renzo-piano/5010012a28ba0d4222000395-california-academy-of-sciences-renzo-piano-photo)*

Figure 58. Live Animals at California Academy of Sciences

Note: *From Pranav Balchandar/tripadvisor (https://www.tripadvisor.com/Attraction_Review-g60713-d117078-Reviews-California_Academy_of_Sciences-San_Francisco_California.html#/media-atf/117078/698679797:p/?albumid=-160&type=0&category=-160)*

Figure 59. Live Plants Throughout California Academy of Sciences



Note: *From Kevan W/tripadvisor (https://www.tripadvisor.com/Attraction_Review-g60713-d117078-Reviews-California_Academy_of_Sciences-San_Francisco_California.html#/media-atf/117078/337220257:p/?albumid=-160&type=0&category=-160)*

Figure 60. Large Glass Façade

Note: *From Tim Griffith via ArchDaily.com (https://www.archdaily.com/6810/california-academy-of-sciences-renzo-piano/5010013a28ba0d422200039a-california-academy-of-sciences-renzo-piano-photo?next_project=no)*

Figure 61. Butterflies and birds in Osher Rainforest

Note: *From California Academy of Sciences (https://www.calacademy.org/exhibits/osher-rainforest)*

Figure 62. Aquariums at California Academy of Sciences

Note: *From California Academy of Sciences (https://www.calacademy.org/exhibits/philippine-coral-reef)*

Figure 63. Shading Devices

Note: *From Tim Griffith via ArchDaily.com (https://www.archdaily.com/6810/california-academy-of-sciences-renzo-piano/5010015228ba0d42220003a2-california-academy-of-sciences-renzo-piano-photo?next_project=no)*

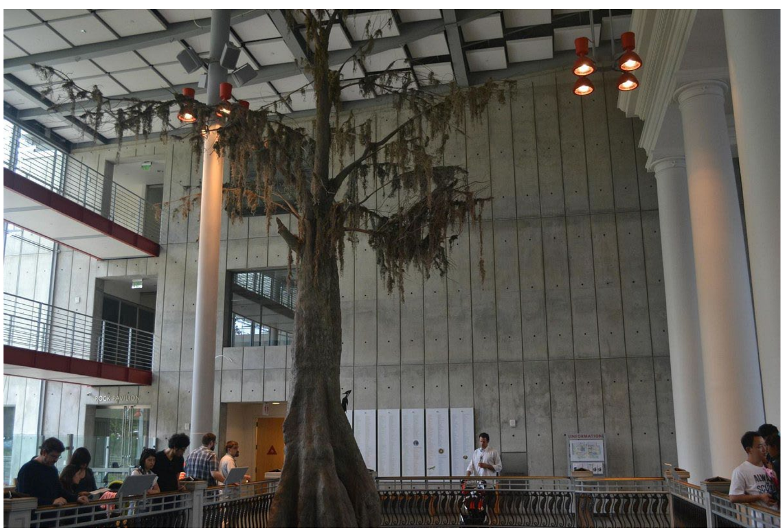
Table 10. Natural Analogues used at the California Academy of Sciences

Natural Analogues	
Pattern	Description of use
Biomorphic Forms & Patterns	• The rainforest backdrop in the dome provides a symbolic reference to natural forms • Wallpapers depicting African landscapes in the African hall mimic the patterns and textures found in these natural settings • The walls in the Water Planet exhibit are shaped with a water ripple form, evoking the fluid patterns of natural water movement
Material Connection with Nature	• Real trees along paths and hallways provide a tactile and visual connection to the local ecology • Utilizing rocks as barrier walls offers a tangible and visual connection to the local geology and creates a naturalistic element within the space
Complexity & Order	• The meandering path through the rainforest dome provides complex sensory information through a naturalistic spatial hierarchy • Hallways in the Water Planet exhibit display a fluid, winding form that guides visitors along a comprehensible path, reflecting the ordered complexity of natural waterways

Figure 64. African Exhibit

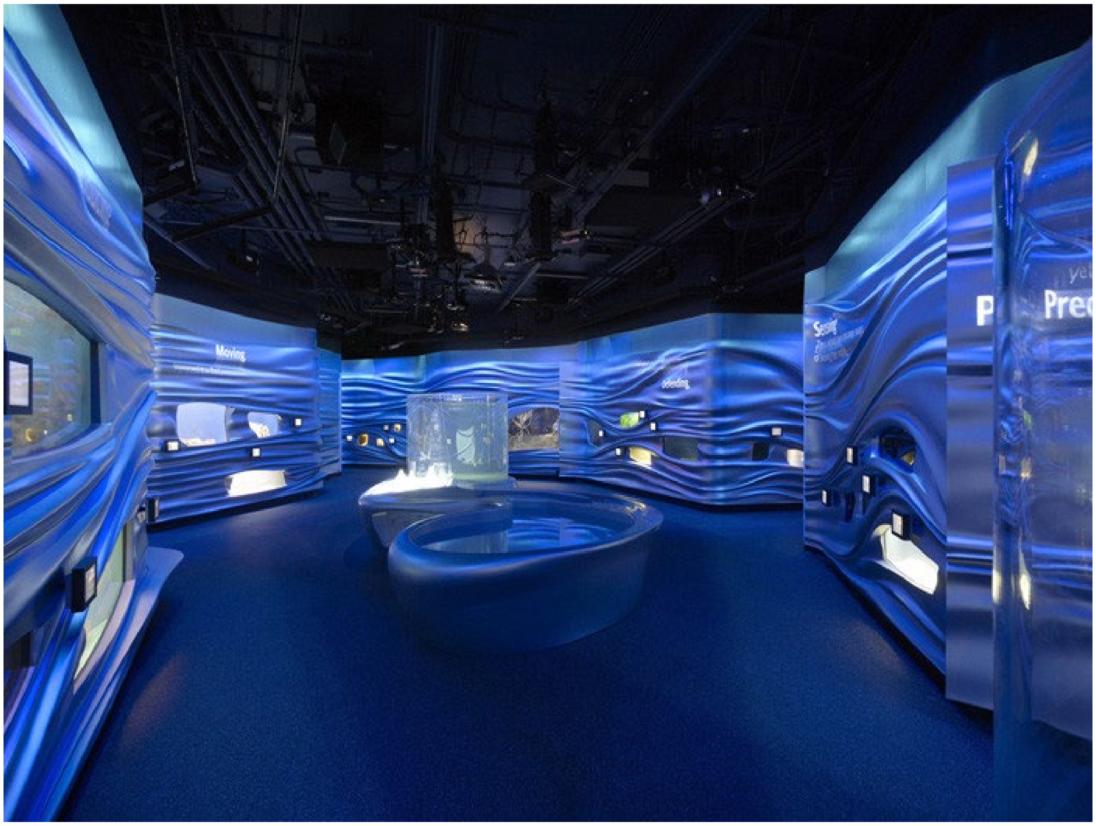
Note: *From Tim Griffith via ArchDaily.com (https://www.archdaily.com/6810/california-academy-of-sciences-renzo-piano/5010014028ba0d422200039c-california-academy-of-sciences-renzo-piano-photo?next_project=no)*

Figure 65. Tree Inside California Academy of Sciences



Note: *From Amit G/tripadvisor (https://www.tripadvisor.com/Attraction_Review-g60713-d117078-Reviews-California_Academy_of_Sciences-San_Francisco_California.html#/media-atf/117078/75125940:p/?albumid=-160&type=0&category=-160)*

Figure 66. Water Planet Exhibit at California Academy of Sciences



Note: *From Tim Griffith via ArchDaily.com (https://www.archdaily.com/6810/california-academy-of-sciences-renzo-piano/5010013128ba0d4222000397-california-academy-of-sciences-renzo-piano-photo?next_project=no)*

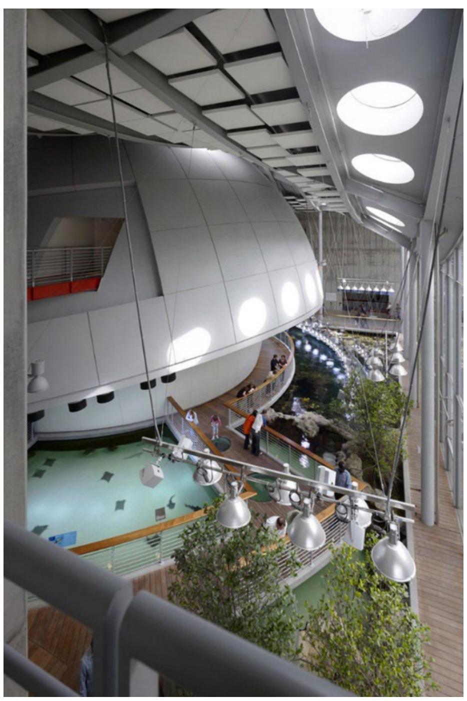
Table 11. Nature of the Space Patterns used at the California Academy of Sciences

Nature of the Space	
Pattern	Description of use
Prospect	• The large windows offering expansive views over Golden Gate Park provide a sense of prospect • Elevated walkways provide views over the multiple floors

Table 11. Nature of the Space Patterns used at the California Academy of Sciences (continued)

Nature of the Space	
Pattern	Description of use
Mystery	• The intriguing design of the large sphere planetarium sparks curiosity about what is inside • walkways and levels that offer views into various spaces evoke a sense of mystery, inviting visitors to explore further
Risk/Peril	• Elevated walkways over the stingray and jungle pools introduce an element of perceived risk while ensuring safety with railings, creating an engaging and thrilling experience high above the water

Figure 67. Interior Overlook of California Academy of Sciences



Note: *From Tim Griffith via ArchDaily.com (https://www.archdaily.com/6810/california-academy-of-sciences-renzo-piano/5010013728ba0d4222000399-california-academy-of-sciences-renzo-piano-photo) By Tim Griffith*

Heureka Science Center - Vantaa, Finland

Heureka Science Center, located in the Tikkurila district of Vantaa, Finland, is a prominent Finnish science center designed by Heikkinen – Komonen Architects. Established in 1989, it aims to popularize scientific knowledge and innovate in science education methods. With an annual footfall of around 300,000 visitors, Heureka stands as one of Finland's major leisure centers. Its name, derived from Archimedes' famous exclamation "Eureka," reflects its mission to instill the joy of discovery in everyone. Heureka is a non-profit entity managed by the Finnish Science Centre Foundation, representing a wide range of stakeholders from the scientific community, education sector, industry, and government (FinnishArchitecture.fi, n.d.).

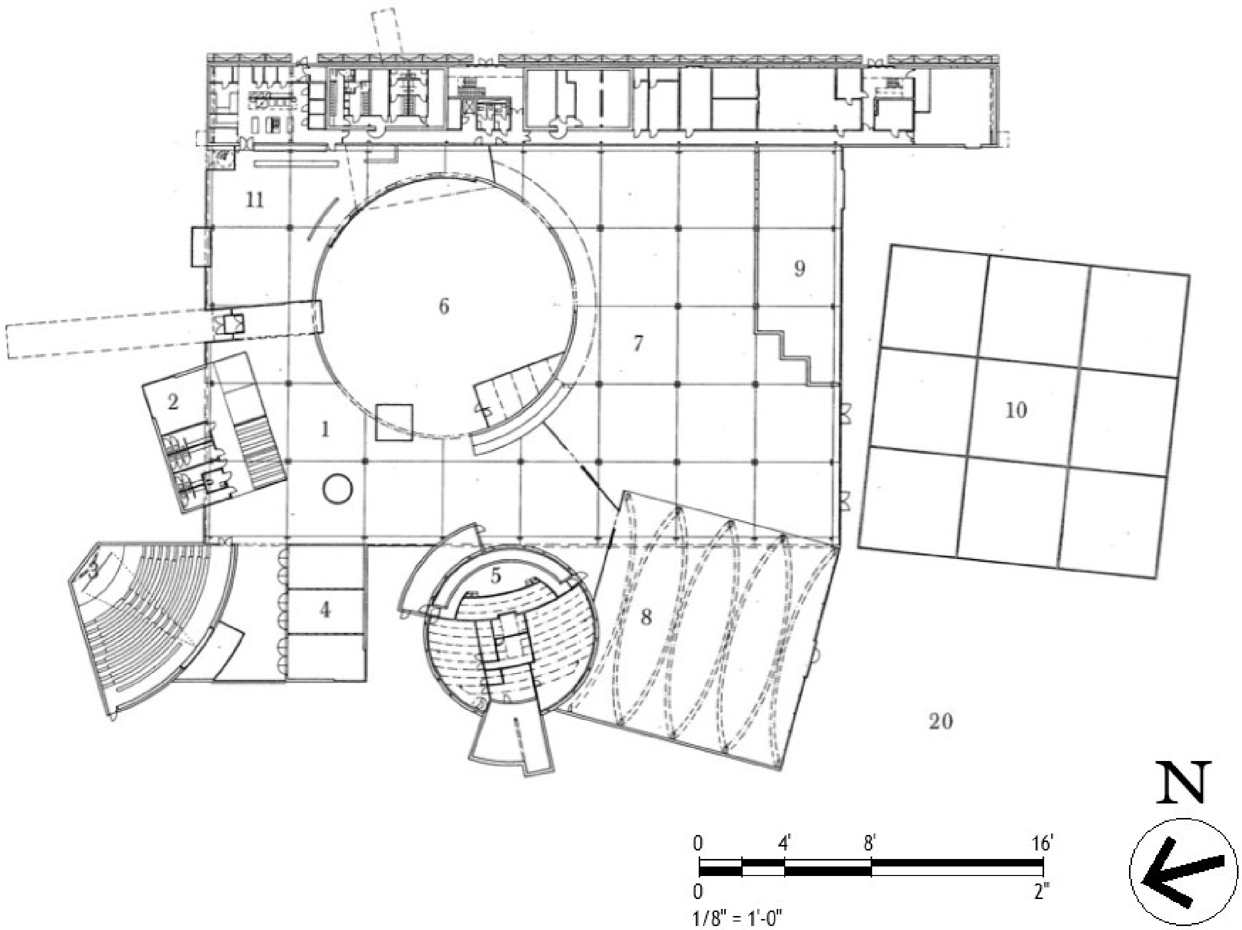
Program and Spatial Analysis. Heureka's program is dynamic and diverse, encompassing permanent and temporary exhibits, a digital planetarium, educational workshops, and various special events. The permanent exhibits cover a wide range of scientific topics, from physical phenomena to technological advancements, encouraging hands-on engagement. The main exhibition area, regularly updated, includes interactive displays on topics like human biology, physics, and environmental science.

Temporary exhibits, changing periodically, bring fresh and often cutting-edge scientific themes to the forefront. These have historically covered subjects from dinosaur biology to the art of filmmaking, attracting a broad audience and keeping the content vibrant and relevant. Additionally, the planetarium, with its 135 seats and advanced digital projection system, offers an immersive experience, showcasing astronomical phenomena and space exploration topics (FinnishArchitecture.fi, n.d.).

The layout of Heureka is deliberately designed to facilitate an exploratory and interactive experience. The main cylindrical exhibition hall, inspired by Gunnar Asplund's design for the Stockholm city library, serves as the heart of the center. Its architecture not only aesthetically pleases but also enhances the display and engagement with the exhibits.

Surrounding the main hall, various smaller exhibit areas and workshop spaces offer more intimate settings for focused learning and hands-on activities. The outdoor area, Science Park Galilei, extends the learning environment beyond the building's walls. This area, functioning as a scientific playground, includes exhibits based on natural phenomena and mathematical concepts, providing a tangible connection between theoretical science and real-world applications (FinnishArchitecture.fi, n.d.).

Figure 68. Heureka Science Center's Floor Plan



Note: *1. Entrance Hall 2. Shop 3. Auditorium 4. Classrooms 5. Theatre 6. Cylindrical Hall/Permanent Exhibition 7. Column Hall/ Permanent Exhibition 8. Vaulted Hall/Changing Exhibition 9. Workshop 10. Outdoor Exhibitions 11. Restaurant. Original Drawing by Heikkinen-Komonen Architect, published in the Finnish Architectural Review 4/1989, Finnish Science Centre Heureka (https://finnisharchitecture.fi/finnish-science-centre-heureka/)*

Figure 69. Heureka Science Center's Layout

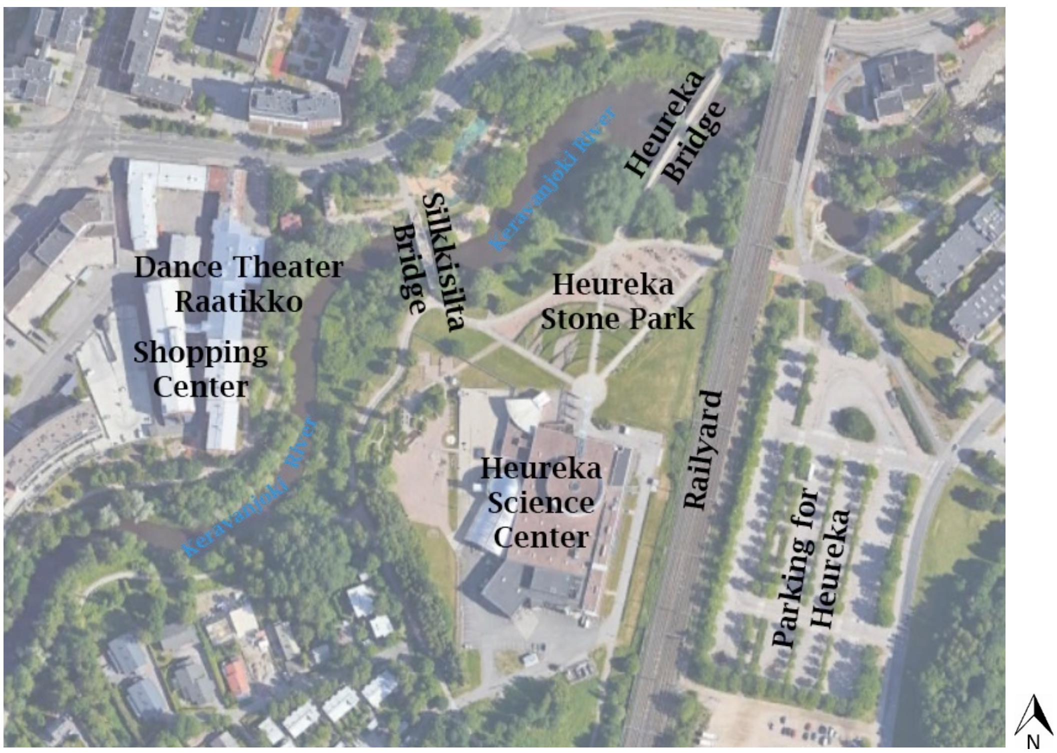
Note: *From Heureka.fi (https://www.heureka.fi/nayttelyt/)*

Site Analysis. Strategically situated at the intersection of the Finnish Main Line and the river Keravanjoki, Heureka's location is both symbolic and functional. The choice of site aligns with its mission to be easily accessible and visibly connected to the larger community. The architecture of Heureka, particularly its facade facing the railway, is designed to mitigate noise while its varied structural components – concrete, steel, and wood – reflect a blend of aesthetics and utility **(FinnishArchitecture.fi, n.d.)**.

Heureka Science Center's development on a brownfield site represents a transformative approach to urban regeneration, highlighting the center's role in revitalizing its surrounding area. Originally a piece of derelict land, the site's transformation into the home of Heureka marked the beginning of significant urban development in the region. The establishment of the science center catalyzed a change in the landscape, turning a neglected area into a vibrant park that now serves as a communal and educational space (Persson P.-E. , 2015).

This redevelopment attracted notable institutions like the National Board of Forests and the Central Criminal Police of Finland, which relocated their headquarters to the vicinity, further signaling the area's renewal. This influx of organizations sparked a wave of urban development, leading to the creation of new housing and office space projects (Persson P.-E. , 2015).

Figure 70. Heureka Science Center's Site Plan



Note: *(Modeled after Google Earth Pro, 2022)*

This initiative reflects Heureka's commitment to environmental sustainability and urban renewal, aligning with its mission to blend scientific exploration with positive community impact. The transformation of this once-neglected area into a thriving hub for education, culture, and business showcases the power of strategic urban development and the significant role that educational institutions can play in it.

Analysis of Biophilic Patterns. The following tables list and describe the biophilic patterns used at Heureka Science Center. Note that not all patterns are used or listed.

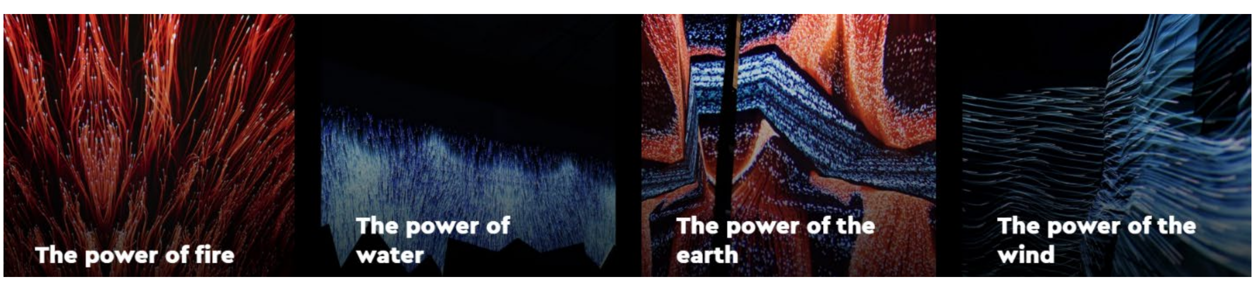
Table 12. Biophilic Patterns used at Heureka Science Center

Nature in the Space	
Pattern	Description of use
Visual Connection with Nature	• The garden views from the restaurant and lobby offer a serene visual link to nature, enhancing the connection to the outdoors
Non-Visual Connection with Nature	• The immersive audio experience in the natural disasters exhibit includes the sounds of fire crackling, water flowing, earth rumbling, and wind howling, creating a realistic and multi-sensory connection to these elemental forces
Non-Rhythmic Sensory Stimuli	• The use of lights and graphics to mimic the movements of different elements in storms is displayed on the walls of the natural disasters exhibit
Dynamic & Diffuse Light	• The dynamic lighting in the natural disasters exhibit is used to simulate the movement and intensity of natural disasters, creating a vivid and changing light environment that mimics natural phenomena • The skylight in the cylindrical hall bathes the interior in natural light, which changes in intensity and angle throughout the day • In the Power of Play exhibit visitors are allowed to create and manipulate shadows, including patterns of trees and leaves
Connection with Natural Systems	• The natural disasters exhibit educates about natural disaster mechanisms, providing insights into these complex natural processes • The Science on the Ball exhibit offers a comprehensive look at Earth's systems, showcasing the planet's dynamic and interconnected natural processes

Figure 71. Garden Views from the Restaurant inside Heureka Science Center

Note: *From Heureka.fi (https://www.heureka.fi/the-science-restaurant/?lang=en)*

Figure 72. In the Middle of Disasters Exhibit at Heureka Science Center



Note: *From Heureka.fi (https://www.heureka.fi/nayttely/katastrofienkeskella/)*

Figure 73. Skylights inside the Cylindrical Hall of Heureka Science Center

Note: *From Areliya/tripadvisor (https://en.tripadvisor.com.hk/LocationPhotoDirectLink-g226906-d1167674-i476202082-Heureka-Vantaa_Uusimaa.html)*

Figure 74. Shadow Patterns in the Power of Play Exhibit at Heureka Science Center

Note: *From Sarah M/tripadvisor (https://en.tripadvisor.com.hk/LocationPhotoDirectLink-g226906-d1167674-i476202082-Heureka-Vantaa_Uusimaa.html)*

Table 13. Natural Analogues used at Heureka Science Center

Natural Analogues	
Pattern	Description of use
Biomorphic Forms & Patterns	• The Wild Wild Wood Exhibit features artistically crafted trees that symbolize the intricate forms found in natural woodlands • The Power of Play exhibit allows visitors to create silhouettes and patterns that resemble those found in natural settings, such as leaves and tree branches • The dynamic lighting in the natural disasters exhibit mimics forms and patterns of elements in natural disaster environments
Material Connection with Nature	• The use of wood in various art installations throughout the Wild Wild Wood exhibit creates a tactile and visual connection to the natural world

Figure 75. Wild Wild Wood Exhibit at Heureka Science Center

Note: *From Heureka Overseas Production LTD (chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://s3-eu-west-1.amazonaws.com/heureka/wp-content/uploads/2020/12/08162331/HOPWildWildWood2020tulostus.pdf)*

Table 14. Nature of the Space Patterns used at Heureka Science Center

Nature of the Space	
Pattern	Description of use
Prospect	• Large Windows the in Restaurant offer sweeping views over the park and train yards, providing a broad perspective and a visual connection to the surrounding landscape

Table 14. Nature of the Space Patterns used at Heureka Science Center (continued)

Nature of the Space	
Pattern	Description of use
Refuge	• Some installations in the Wild Wild Wood exhibit offer an enclosed, intimate space, providing a sense of safety and retreat from the larger exhibition area • Tunnels in the Power of Play exhibit offer a playful and secure environment for children, reminiscent of natural burrows or dens
Mystery	• The intentional design of the exhibit layout, with its non-linear paths and partially obscured views, piques curiosity and encourages visitors to explore further, much like a journey through a natural landscape
Risk/Peril	• A Bicycle Tightrope Ride across one of the main exhibit halls offers an exhilarating experience that simulates the thrill of risk in a completely secure setting by being safely tethered and with a net below

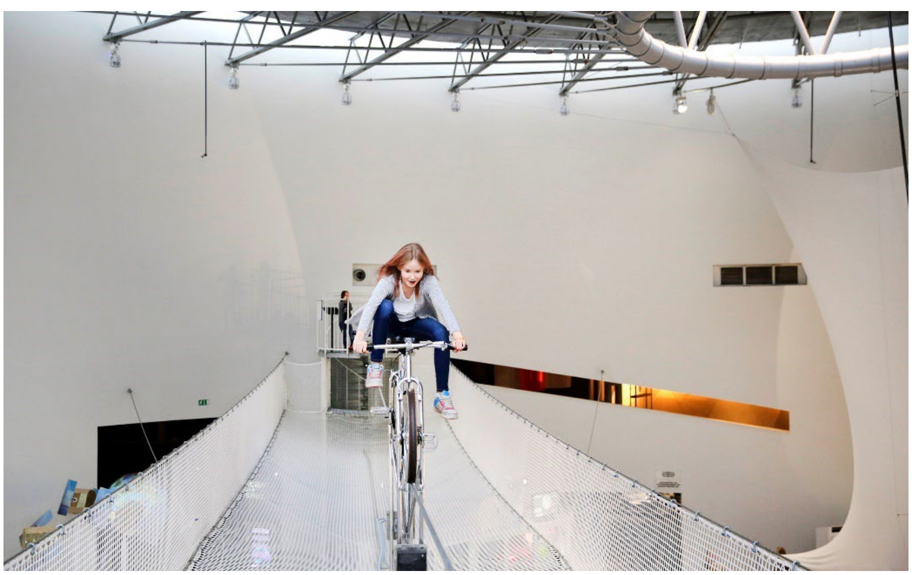
Figure 76. Large Windows in the Front of Heureka Science Center

Note: *From Valentin47/tripadvisor (https://en.tripadvisor.com.hk/LocationPhotoDirectLink-g226906-d1167674-i476202082-Heureka-Vantaa_Uusimaa.html)*

Figure 77. Wild Wild Wood Exhibit Enclosed Art Piece

Note: *From Mikael F/tripadvisor (https://en.tripadvisor.com.hk/Attraction_Review-g226906-d1167674-Reviews-Heureka-Vantaa_Uusimaa.html#/media-atf/1167674/476202089:p/?albumid=-160&type=0&category=-160)*

Figure 78. Bicycle Attraction at Heureka Science Center



Note: *From Berloga Workshop (https://berloga-workshop.com/blog/930-heureka-helsinki.html)*

Analysis of Case Studies

Table 15. Biophilic Patterns Analysis of Case Studies

	Visual Connection with Nature	Non-Visual Connection with Nature	Non-Rythmic Sensory Stimuli	Thermal & Airflow Variability	Presence of Water	Dynamic & Diffused Light	Connection with Natural Systems	Biomorphic Forms & Patterns	Material Connection with Nature	Complexity & Order	Prospect	Refuge	Mystery	Risk/Peril	Totals
ECHO Leahy Center for Lake Champlain	3	3	1	0	3	2	3	3	1	1	2	2	1	1	26
Children's Museum and Theatre of Maine	2	2	2	0	2	2	2	2	1	1	1	2	1	1	21
California Academy of Sciences	3	3	2	1	3	3	3	3	2	2	2	0	2	1	30
Heureka Science Center	1	1	1	0	0	2	2	2	1	0	1	2	1	2	16

Note: *Each case study is graded on the frequency of biophilic patterns used, scaled from 0-3. 0 = No Use of Biophilic Pattern in an exhibit/feature in the case study. 1 = One use of a biophilic pattern in an exhibit/feature in the case study. 2 = 2-3 times a biophilic pattern is used in an exhibit/feature in the case study. 3 = > 3 times a biophilic pattern is used in an exhibit/feature in the case study.*

Summary of Case Studies

The comparative analysis of these four distinct institutions reveals a varied implementation of biophilic design principles, each tailored to their specific context and educational objectives. The California Academy of Sciences stands out for its extensive use of biophilic patterns, reflecting its status as the largest among the studied centers. Its design intricately integrates elements of nature, from live animal habitats to dynamic lighting systems, exemplifying a comprehensive approach to biophilic design.

Conversely, Heureka Science Center, while incorporating fewer biophilic elements, demonstrates a unique application of these principles. Particularly notable is its Natural

Disasters exhibit, where its dynamic lighting creatively represents the forms and movements of natural elements, showcasing an innovative approach to environmental storytelling.

A common thread among three of the four centers is the use of live animal exhibits, which serve to deepen the visitors' connection with natural ecosystems. However, it was the ECHO Leahy Center for Lake Champlain that uniquely combined these exhibits with educational spaces like classrooms and laboratories for the local university, underscoring its commitment to hands-on learning and scientific inquiry.

Interactive exhibits are a universal feature across all centers, engaging visitors in immersive and participatory experiences. This interactive aspect not only enhances the learning experience but also fosters a deeper understanding and appreciation of natural systems.

Another notable aspect is the adaptive reuse of brownfield sites by half of the centers. This approach not only speaks to the centers' commitment to sustainability but also to the revitalization of urban spaces, demonstrating how science centers can serve as catalysts for environmental and community regeneration.

The case studies collectively illustrate that the application of biophilic design in science centers is not just about the number of patterns used, but also about the creativity and effectiveness of their implementation. Each center, regardless of its scale or focus, contributes uniquely to the promotion of environmental awareness and education, showcasing the versatility and impact of biophilic design in public educational spaces.

Project Location (Larger Scale)

Fargo Area

History. The Fargo-Moorhead area, straddling the border between North Dakota and Minnesota, has a rich history dating back to its early settlement in the 19th century. Originally, the area was inhabited by various Native American tribes, including the Dakota and Ojibwa **(NDSU Archives, n.d.)**. The first European-American settlers arrived in the early 1870s, drawn by the promise of land and resources **(The City of Fargo, n.d.)**.

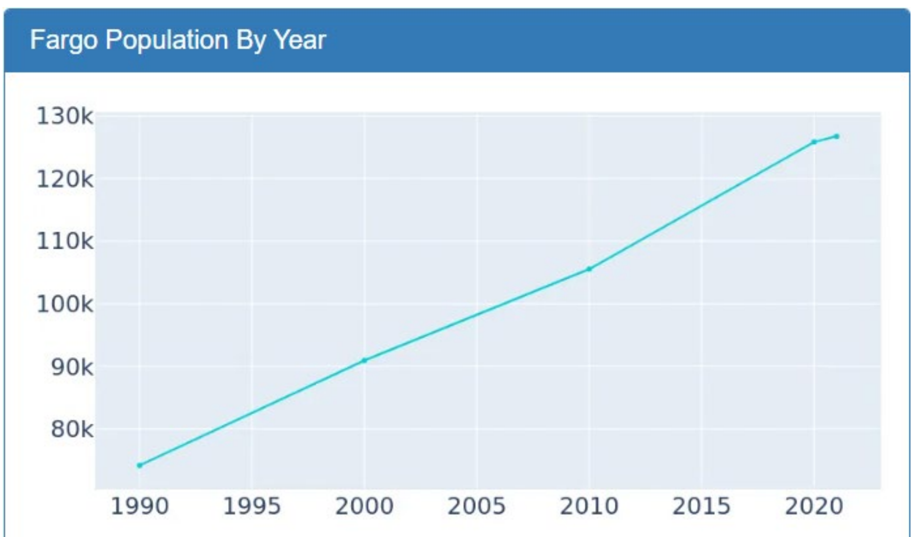
In 1871, the Northern Pacific Railway reached the area, and the city of Fargo was founded alongside it. The city was named after William G. Fargo, a director of the Northern

Pacific Railroad and co-founder of the Wells Fargo Express Company. The railroad's arrival catalyzed the area's growth, with Fargo quickly becoming a bustling hub for trade and agriculture (The City of Fargo, n.d.).

A pivotal moment in Fargo's history was the devastating fire of 1893. The fire destroyed much of the city's central business district. However, the disaster also led to a period of rapid rebuilding and growth. The city was reconstructed with more durable materials, and during this time, Fargo emerged as an economic and cultural center in the region (NDSU Archives, n.d.).

Population. The Fargo-Moorhead area, comprising Fargo, North Dakota, and its adjacent cities, including Moorhead, Minnesota, has experienced notable growth over the years. Fargo, as the most populous city in North Dakota, has seen its population increase significantly, reflecting the region's economic and cultural development.

Figure 79. Chart of Fargo’s Population Growth



Year	Population	Rank in US	Growth Rate
2021	126,748	219	0.7%
2020	125,853	223	1.8%
2010	105,549	253	1.5%
2000	90,951	275	2.1%
1990	74,195	304	–

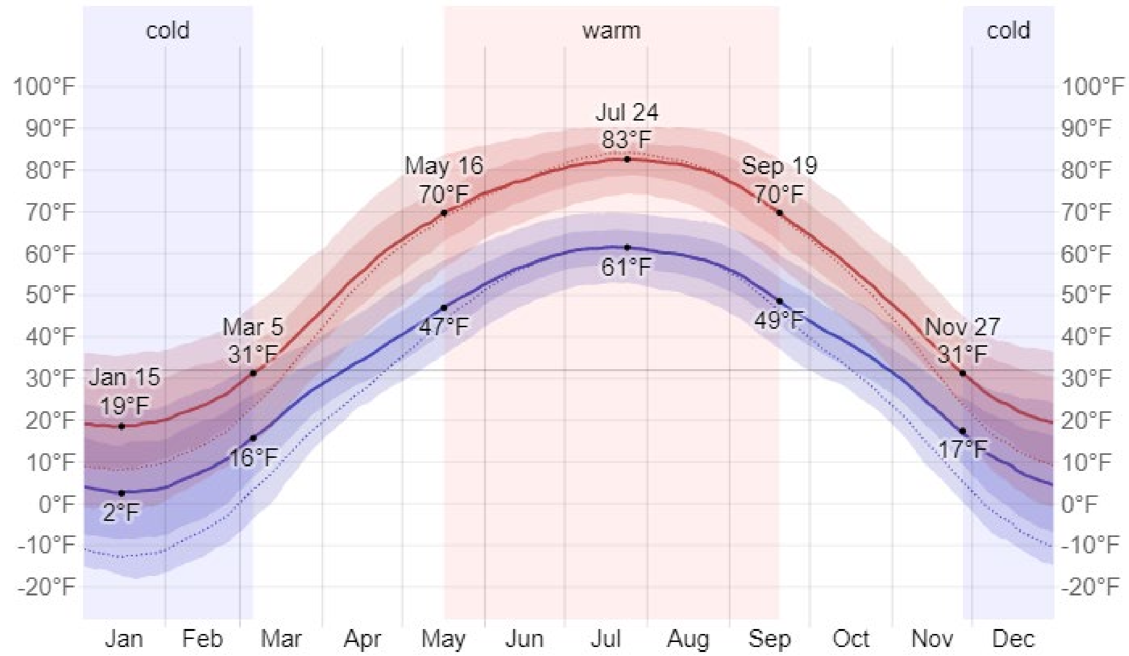
Note: *Data from U.S. Census Bureau, chart from Biggest US Cities (https://www.biggestuscities.com/city/fargo-north-dakota)*

Fargo's growth has been somewhat faster than similar-sized cities in the U.S. Between 2000 and 2021, Fargo's population grew by 39.3%, which is 74% faster than many other cities of comparable size (Biggest US Cities, n.d.). The Fargo-Moorhead Metropolitan Statistical Area (MSA) which includes Fargo and its neighboring cities, has an estimated population of 258,663 as of 2022 (U.S. Census Bureau, n.d.).

Climate. The climate of the Fargo-Moorhead area is characterized by its distinct humid continental climate, which brings about a wide range of weather conditions throughout the year. Fargo is in the USDA Plant Hardiness Zone 4a **(USDA, n.d.)**. This region experiences four distinct seasons, each with its own unique characteristics. Winters are notably cold and snowy, reflecting the area's northern latitude and inland location. Spring brings a gradual warming trend, often accompanied by increased precipitation and the potential for flooding, particularly due to the melting snow from the winter months. Summers in Fargo-Moorhead are typically warm and can be humid, providing a stark contrast to the frigid winter months. Finally, autumn is marked by cooler temperatures and a decrease in humidity, making it a season of comfortable weather before the onset of winter **(Weather Spark, n.d.)**.

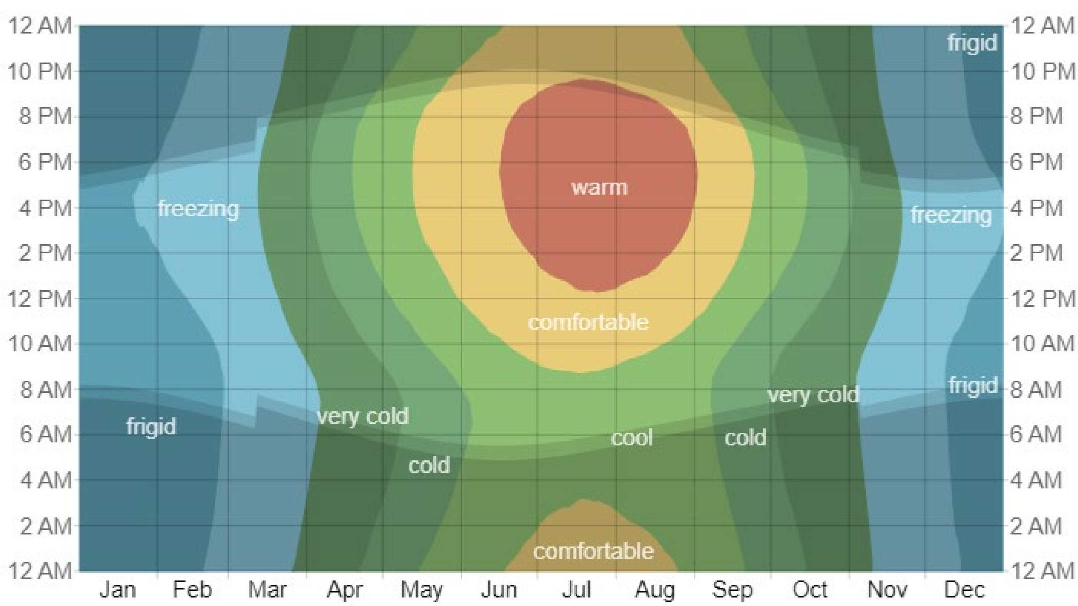
Temperature. The Temperature in Fargo changes drastically throughout the year. The warmer months are from mid-May to mid-September where the average daily high temperature is over 70˚F ***(Weather Spark, n.d.)***. The colder months in Fargo are from November to March with the average daily high temperature below 31˚F.

Figure 80. Fargo's Average High and Low Temperatures



Note: *The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures, From WeatherSpark.com (https://weatherspark.com/y/9084/Average-Weather-in-Fargo-North-Dakota-United-States-Year-Round#google_vignette)*

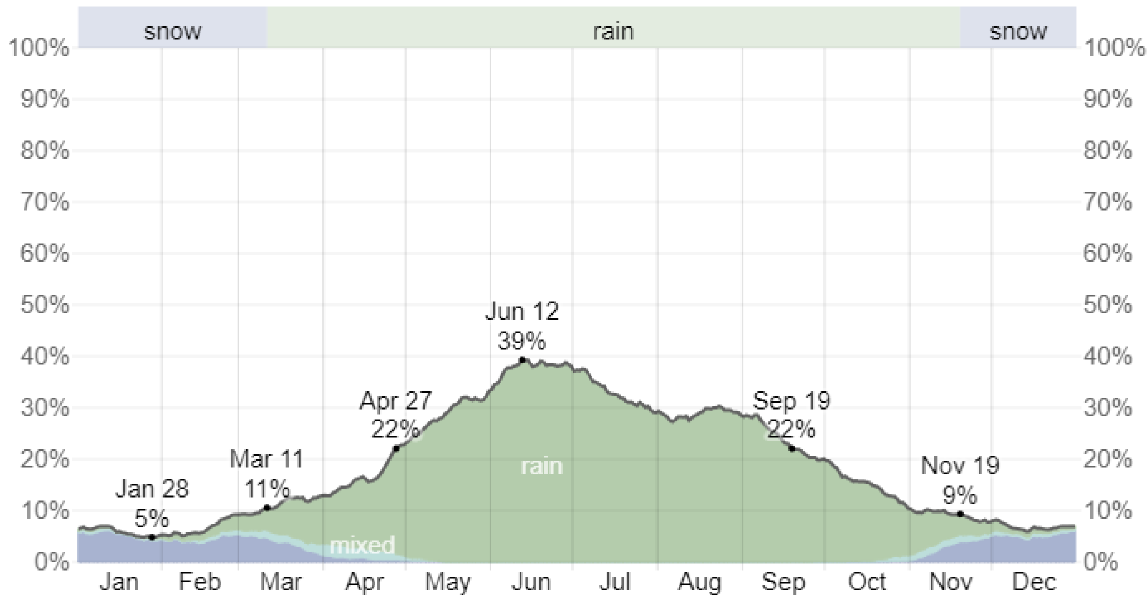
Figure 81. Fargo's Average Hourly Temperature



Note: *Shaded regions represent night and civil twilight, From WeatherSpark.com (https://weatherspark.com/y/9084/Average-Weather-in-Fargo-North-Dakota-United-States-Year-Round#google_vignette)*

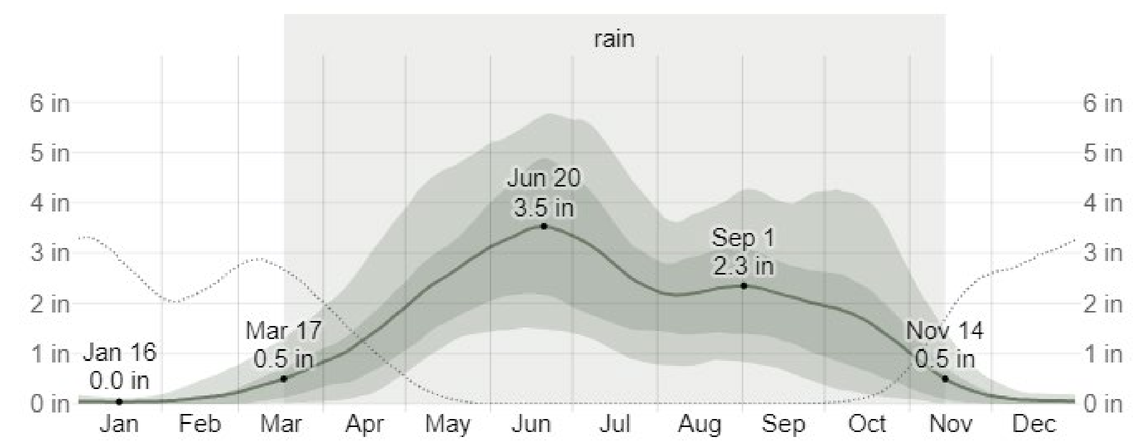
Precipitation. Fargo gets a mix of both rain and snow, the month with the most rain is June, and the month with the most average snowfall is January.

Figure 82. Fargo's Daily Chance of Precipitation



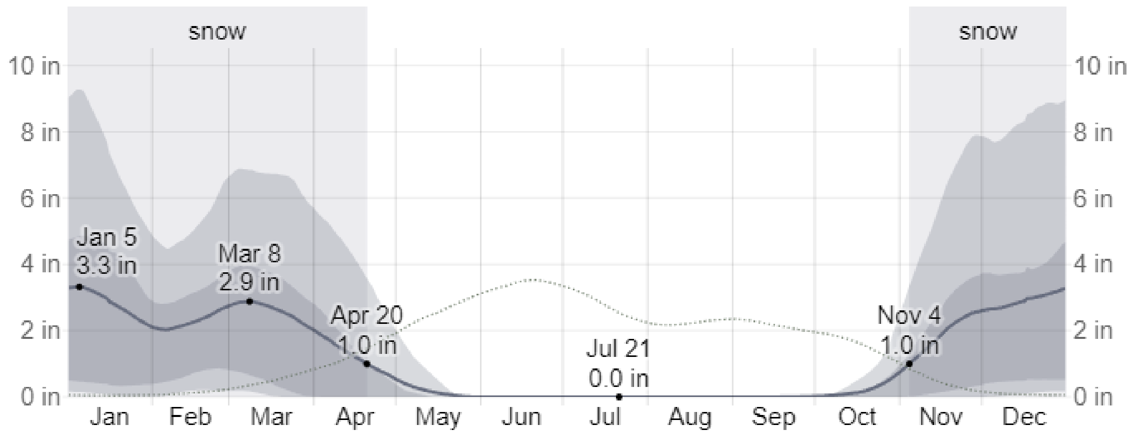
Note: *From WeatherSpark.com (https://weatherspark.com/y/9084/Average-Weather-in-Fargo-North-Dakota-United-States-Year-Round#google_vignette)*

Figure 83. Fargo's Average Monthly Rainfall



Note: *The average rainfall (solid line) accumulated over the course of a sliding 31-day period centered on the day in question, with 25th to 75th and 10th to 90th percentile bands. The thin dotted line is the corresponding average snowfall, From WeatherSpark.com (https://weatherspark.com/y/9084/Average-Weather-in-Fargo-North-Dakota-United-States-Year-Round#google_vignette)*

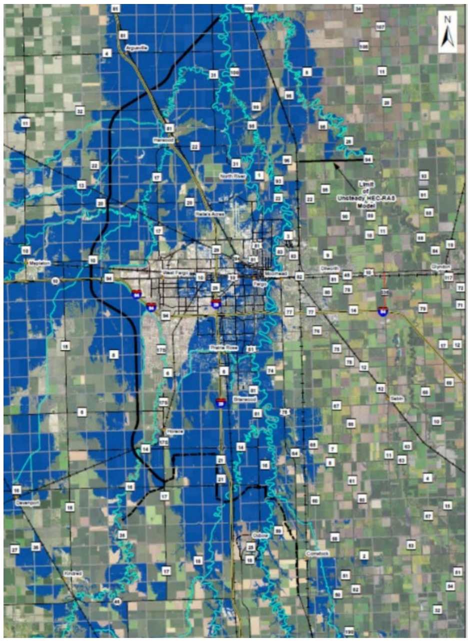
Figure 84. Fargo's Monthly Average Snowfall



Note: *The average snowfall (solid line) accumulated over the course of a sliding 31-day period centered on the day in question, with 25th to 75th and 10th to 90th percentile bands. The thin dotted line is the corresponding average rainfall, From WeatherSpark.com (https://weatherspark.com/y/9084/Average-Weather-in-Fargo-North-Dakota-United-States-Year-Round#google_vignette)*

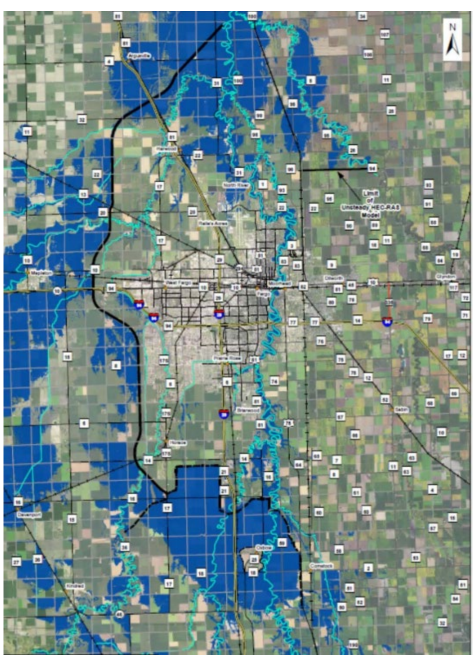
Flooding. With the combination of snowfall and long periods of cold weather without above-freezing temperatures, the Fargo area experiences flooding nearly every year in the Spring. In the Fall heavy rains can create high soil moisture conditions going into winter, this has also been found to be a factor in Fargo's historic floods ***(Wood, 2019).*** Some years flooding is worse than others, some of the notably worst floods in Fargo's past are: in 2009 where the Red River crested at 40.48 feet, in 1997 where the Red River Crested at 39.72 feet, in 1897 where the Red River crested at 39.1 feet, in 2011 where the Red River crested at 38.81 feet, and in 1969 where the Red River crested at 37.34 feet ***(National Weather Service, 2020).*** As discussed earlier in the Red River Region Chapter, the Fargo/Moorhead area will soon be protected against flooding with the diversion project that will significantly lower the flood water levels of the Red River in the Fargo/Moorhead area.

Figure 85. Before Diversion Fargo/Moorhead 100-Year Flood Zones Map



Note: *The black line represents the diversion path, and the dark blue represents the FEMA's 100-year flood zones. From Metro Flood Diversion Authority (https://fmdiversion.gov/land-management/maps/)*

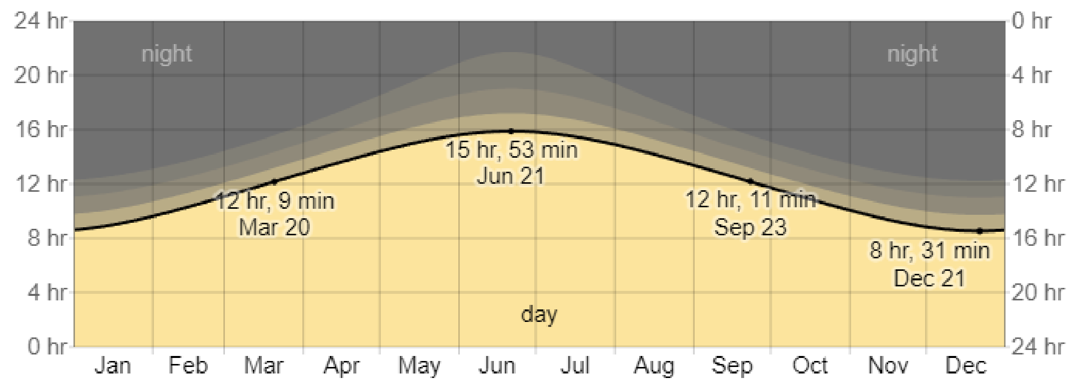
Figure 86. After Diversion Fargo/Moorhead 100-Year Flood Zones Map



Note: *The black line represents the diversion path, and the dark blue represents FEMA's 100-year flood zone estimated change after the project's completion. From Metro Flood Diversion Authority (https://fmdiversion.gov/land-management/maps/)*

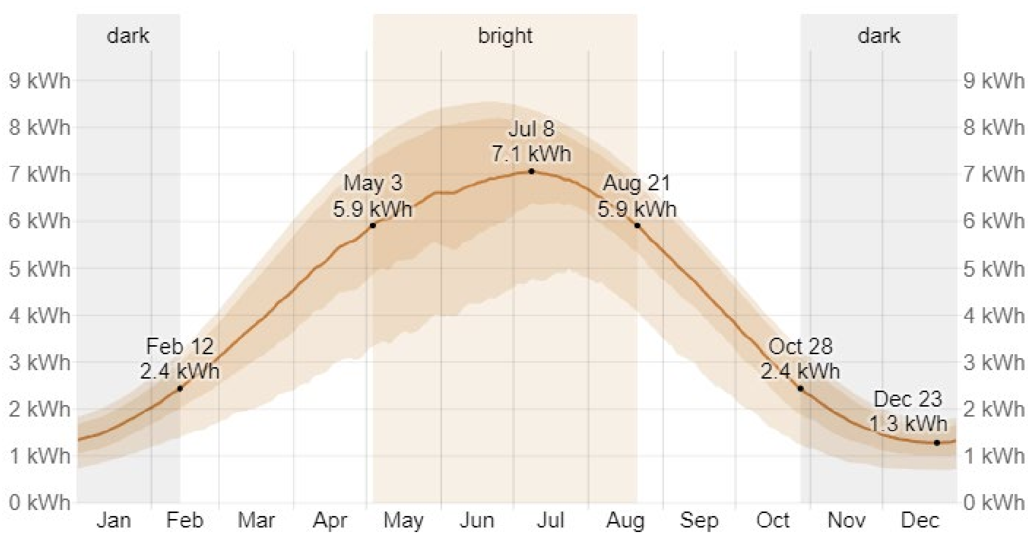
Sun. Being that Fargo is so far north, the length of daylight varies significantly throughout the year. In Fargo, the month with the most amount of daylight is June, with 15.8 hours of daylight. The month with the least amount of daylight is December, with 8.6 hours of daylight ***(Weather Spark, n.d.).***

Figure 87. Hours of Daylight and Twilight in Fargo



Note: *The number of hours during which the Sun is visible (black line). From bottom (most yellow) to top (most gray), the color bands indicate full daylight, twilight (civil, nautical, and astronomical), and full night. From WeatherSpark.com (https://weatherspark.com/y/9084/Average-Weather-in-Fargo-North-Dakota-United-States-Year-Round#google_vignette)*

Figure 88. Average Daily Shortwave Solar Energy in Fargo

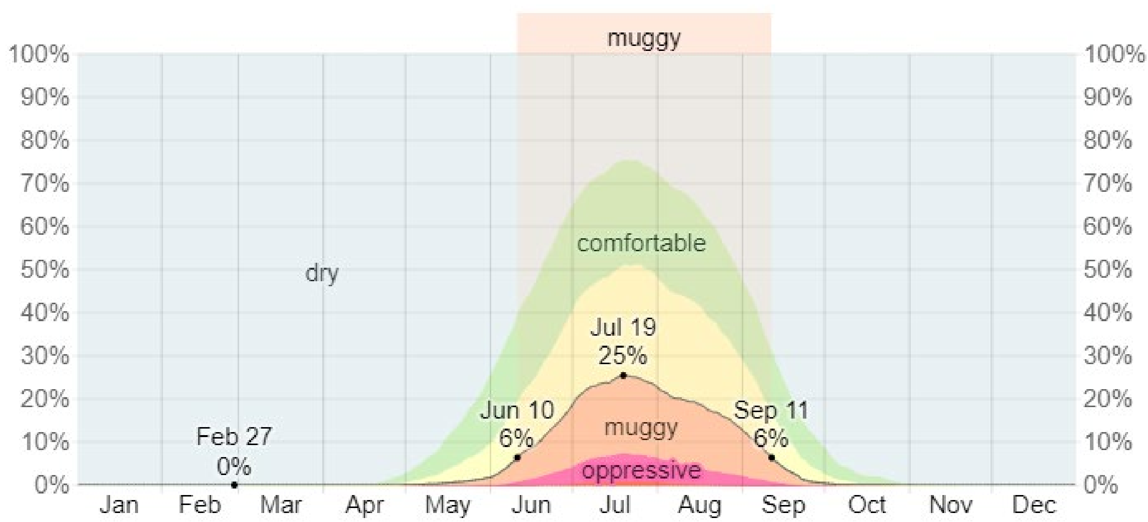


Note: *The average daily shortwave solar energy reaching the ground per square meter (orange line), with 25th to 75th and 10th to 90th percentile bands. From WeatherSpark.com (https://weatherspark.com/y/9084/Average-Weather-in-Fargo-North-Dakota-United-States-Year-Round#google_vignette)*

Humidity. Humidity levels are primarily assessed based on the dew point, which is crucial in determining the rate at which sweat evaporates from the skin, thereby affecting body cooling. A lower dew point is associated with drier conditions, while a higher dew point indicates more humidity. Contrasting with temperature, which can fluctuate significantly from day to night, changes in dew point are more gradual. Consequently, a humid day often leads to a similarly humid night ***(Weather Spark, n.d.).***

Seasonally, Fargo's humidity varies. The most humid part of the year spans about three months, from June to September. July typically has the highest number of muggy days, averaging around 7.3 such days (Weather Spark, n.d.). On the other hand, late February is usually the least muggy time of the year, with muggy conditions being virtually non-existent (Weather Spark, n.d.).

Figure 89. Humidity Comfort Levels in Fargo

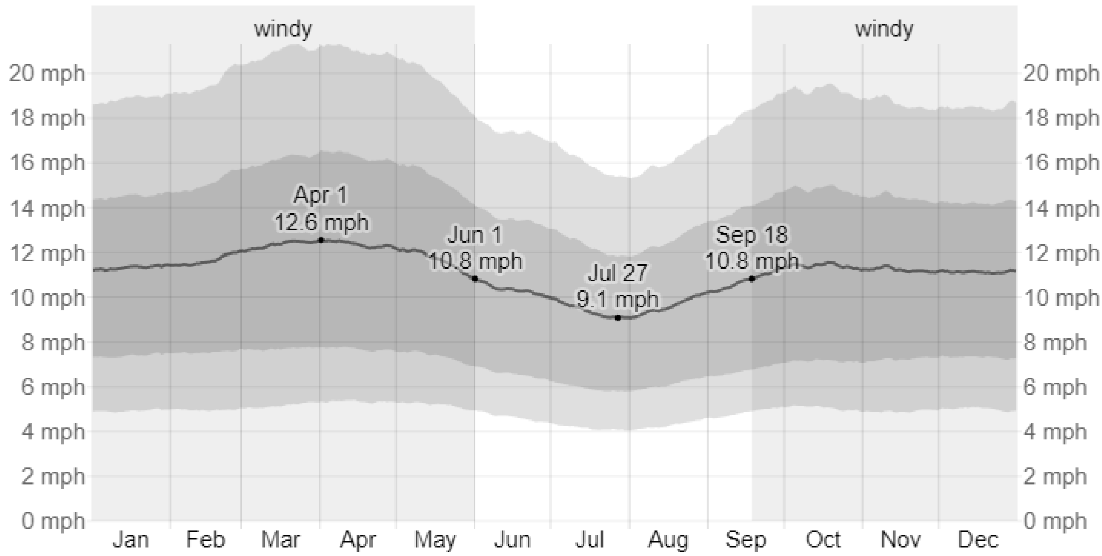


Note: *The percentage of time spent at various humidity comfort levels, categorized by dew point. From WeatherSpark.com (https://weatherspark.com/y/9084/Average-Weather-in-Fargo-North-Dakota-United-States-Year-Round#google_vignette)*

Wind. Fargo experiences a significant variation of wind speeds throughout the year, The windier part of the year lasts 8 months, from September to June, with the windiest month being

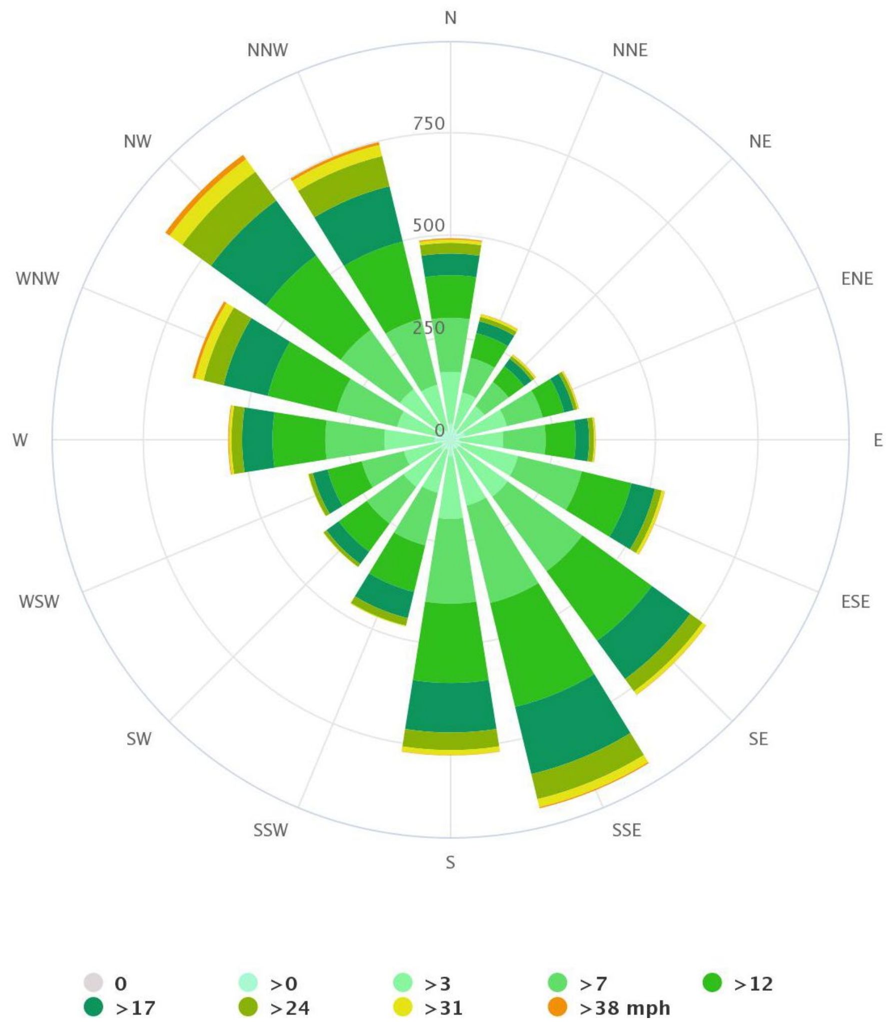
March ***(Weather Spark, n.d.).*** The calmer months are from June to September with the calmest month being July ***(Weather Spark, n.d.).***

Figure 90. Fargo's Average Wind Speed



Note: *The average of mean hourly wind speeds (dark gray line), with 25th to 75th and 10th to 90th percentile bands. From WeatherSpark.com (https://weatherspark.com/y/9084/Average-Weather-in-Fargo-North-Dakota-United-States-Year-Round#google_vignette)*

Figure 91. Wind Rose for Fargo



Note: *The wind rose shows how many hours per year the wind blows from the indicated direction. From meteoblue.com (https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/fargo_united-states_5059163)*

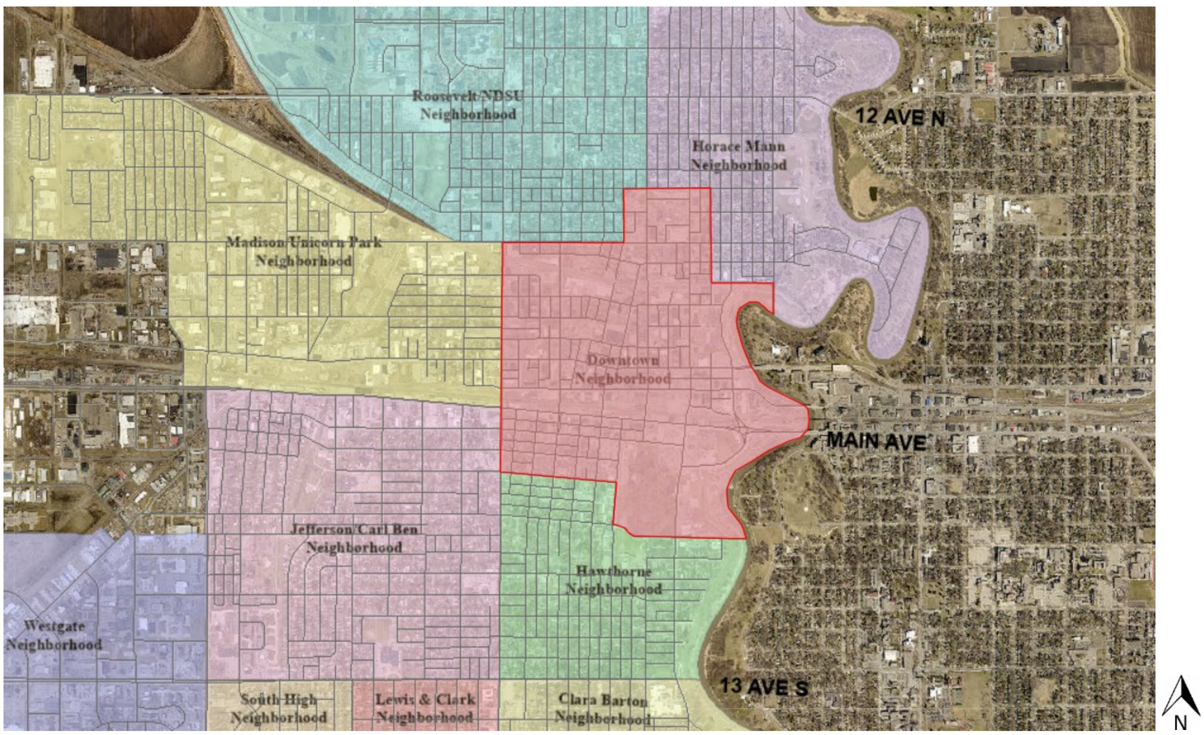
Project Location (Smaller Scale)

Downtown Fargo

Downtown Fargo, once the central business district and core of the community, has evolved significantly over the past century, transitioning from a primary shopping area to a vibrant mixed residential and commercial district. With a size of .810 square miles, downtown Fargo has a population of 5,266. Of these residents 77% are renters and 23% own their properties (Niche, n.d.). This urban center is a dynamic blend of living and commercial spaces.

It offers residents, workers, and visitors a range of amenities such as riverfront access, parks, trails, entertainment, and shopping opportunities. The outskirts are characterized by single-family homes, while a variety of other housing options are available in the interior. The development of downtown Fargo has been further stimulated by the Renaissance Zone and Neighborhood Revitalization Initiatives, leading to a significant surge in both commercial and residential growth (The City of Fargo, n.d.).

Figure 92. Neighborhood Map of Fargo



Note: *The downtown neighborhood is colored red. From The City of Fargo GIS (https://gis.cityoffargo.com/link/jsfe/index.aspx)*

History. The founding and development of downtown Fargo is deeply intertwined with the advent of the railroad and its strategic location along the Red River. Fargo's origin dates back to 1871 when it was established at the crossing of the Northern Pacific Railroad and the

Red River. This pivotal location contributed significantly to its rapid growth as a hub for regional commerce, manufacturing, and trade **(The City of Fargo, n.d.) (ACHP, n.d.).**

Originally, two small communities emerged on the west side of the river: "Fargo in the Timber" along the riverbanks and "Fargo on the Prairie," roughly at the current intersection of Broadway and Front Street (now Main Avenue). "Fargo on the Prairie" served as the headquarters for the Northern Pacific engineers and their families, as well as accompanying Army officers, forming a community of around 100 people living in about fifty tents (NDSU Archives, n.d.).

In the latter part of the 20th century, like many other American cities, downtown Fargo faced challenges due to the development of regional shopping malls. However, the creation of a State Renaissance Zone revitalized the downtown area through a mix of tax exemptions and credits, leading to significant redevelopment that included historic preservation elements. Since 2000, this initiative has led to a substantial increase in property values in the downtown area (ACHP, n.d.).

Today, downtown Fargo is a vibrant mix of historic and modern elements, with many buildings of historic value having been transformed. It serves as a testament to the city's ongoing commitment to preserving its rich history while adapting to contemporary needs.

Figure 93. Downtown Fargo's Historic Black Building

Note: *The Black Building, established in 1931 and once the tallest in North Dakota, epitomizes Fargo's historical and architectural heritage, symbolizing the enduring spirit of downtown Fargo. From Downtown Community Partnership (https://downtownfargo.com/downtown-fargo-history/)*

Characteristics. Downtown Fargo, evolving from its early days as a rugged frontier town, now stands as a cosmopolitan neighborhood embodying the live-work-play ethos. This transformation has been largely fueled by innovative programs and partnerships that have revitalized old buildings, converting them into modern living spaces like apartments, condominiums, and boutique hotels **(American Planning Association, 2009).** This rejuvenation has, in turn, attracted trendy restaurants, unique shops, and chic galleries, catering to a diverse clientele. The area, roughly spanning 100 blocks, is bordered by the Red River of the North and University Drive, and extends from 7th and 9th Avenues North to 3rd and 6th Avenues South.

Since 1999, over $100 million in public and private investments have been channeled into the 39-block Renaissance Zone, significantly transforming the downtown landscape **(American Planning Association, 2009).**

The area is not just a commercial hub but also includes open spaces and recreational areas like the 45-acre Island Park, a community gathering space with a swimming pool, and the Dike East recreation area, popular for sledding in winter. Fargo's commitment to historic preservation is evident in the Downtown Fargo Historic District, which includes over 160 properties that have been preserved or renovated with state and federal tax incentives (American Planning Association, 2009). Environmental sustainability is also a key focus, with initiatives like green roofing and the city's use of biodiesel in public transportation contributing to a greener downtown Fargo (American Planning Association, 2009).

Specific Site

106 Northern Pacific Ave, Fargo, ND 58102

Figure 94. Site

Note: *From The City of Fargo GIS (https://gis.cityoffargo.com/link/jsfe/index.aspx)*

Site Selection

The chosen site for the Science Center, in close proximity to the Red River, is an ideal location that aligns perfectly with the center’s focus on the Red River Valley and the river itself. This proximity not only provides an authentic and immediate connection to the subject matter but also offers unique opportunities for outdoor educational programs and direct observation of the river's ecosystem. The nearby green spaces, walking paths, and parks complement the center's emphasis on environmental education and outdoor learning, allowing for an expansive educational experience that extends beyond the confines of the indoor exhibits.

Positioned within a designated renaissance zone, the site presents a strategic opportunity for urban renewal and revitalization. The city's interest in utilizing this space, coupled with the lack of a defined purpose until now, underscores the potential of the Science Center to become a cornerstone in the area's redevelopment. The transformation of a brownfield site into a vibrant educational and cultural hub will not only rejuvenate the immediate vicinity but also serve as a catalyst for broader urban regeneration.

Furthermore, the redevelopment of the Moorhead Mall in the future will synergize with the Science Center project, creating a comprehensive redevelopment initiative in the area. This alignment of redevelopment efforts magnifies the potential impact of the Science Center, turning it into a significant contributor to the region’s educational, cultural, and economic landscape. The selection of this site, therefore, is a strategic decision that leverages geographic, cultural, and urban development factors to maximize the Science Center's impact on the community and the region.

Figure 95. Moorhead Mall Redevelopment Plan

Note: *The revitalization of the site could increase the value of the site from $20 million to $200-$250 million once complete, City Manager Dan Mahli said. From Moretomoorhead.com (https://www.moretomoorhead.com/)*

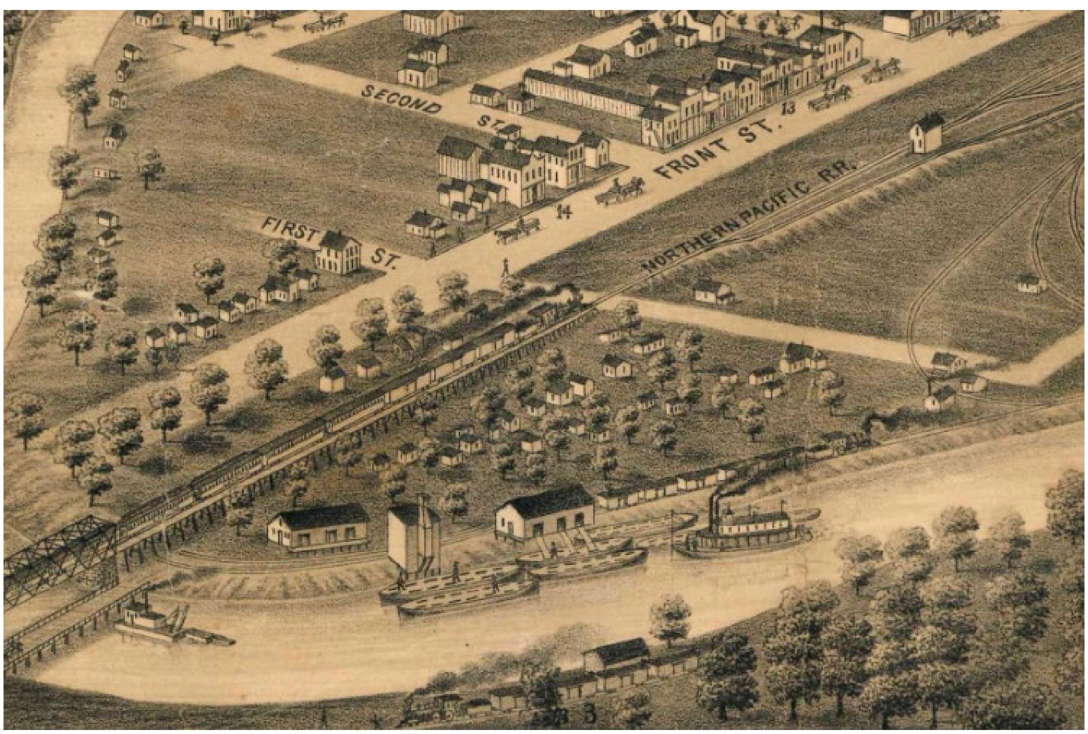
Site History

In the late 1800s, this riverside property was a bustling hub, perfectly poised for riverboats to dock. It witnessed the rise of Fargo’s first residential settlements along the riverbanks, although only humble shanties housing a population grappling with poverty. This area, according to the insights of Mark Peihl, senior archivist with the Historical and Cultural Society of Clay County, was more than an industrial locale; it was a cradle of community life. Notably, around 1890, amidst the industrial bustle, a kindergarten was established to serve the children of this neighborhood, many of them immigrants learning English, a testament to the area's role in the socio-cultural fabric of Fargo (Peihl, 2018).

The site's industrial legacy continued to evolve, housing various enterprises including a lumber company and the Fargo Foundry, the precursor to Mid-America Steel. However, the location was not just a witness to industrial growth. It played a pivotal role in the transportation history of Fargo and Moorhead, particularly with the advent of electric streetcars around the early 20th century. The first streetcar maintenance building was situated here, and a bridge used by the streetcars stood until the early 1940s – its remnants, the pylons, are occasionally visible in the river (Peihl, 2018). Streetcar No. 28, which served Concordia College and later became a historical artifact, underscores the site's significance in local transit history (Peihl, 2018).

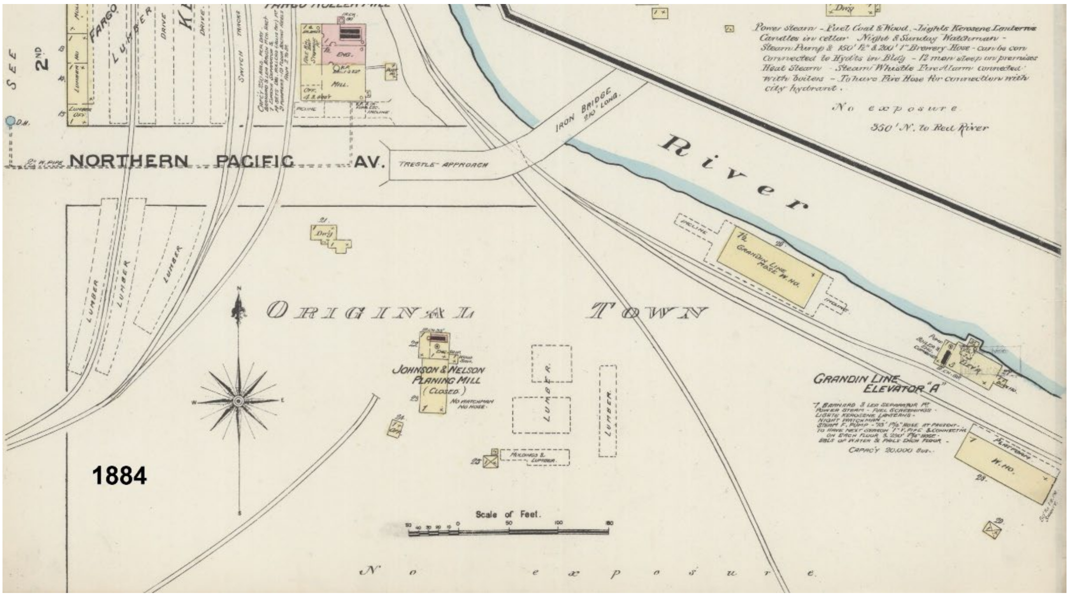
The transformation of this site over the years reflects the city's evolution. From the industrial boom represented by "Machinery Row" in the early 20th century to the gradual shift to steel fabrication in the mid-1900s, and finally to its recent vacancy and readiness for redevelopment – each phase mirrors changes in Fargo's economic and urban landscape. The fire in 2021 that led to the demolition of most of the building marks an end of an era and a transition to a new chapter.

Figure 96. Drawing of Site from 1880



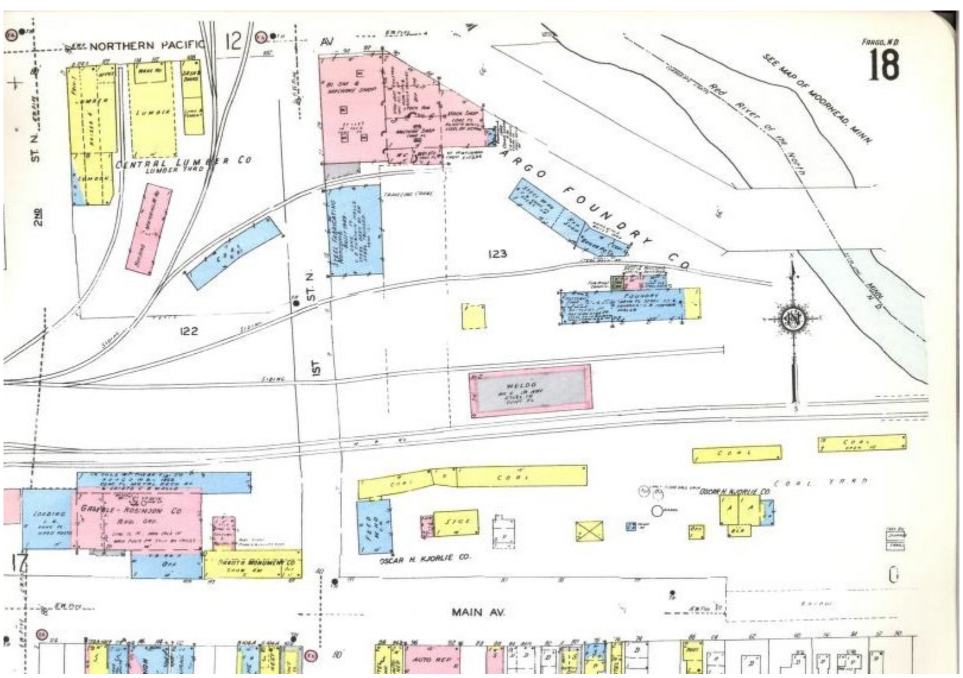
Note: *From Historical & Cultural Society of Clay County, Received from Archivist Mark Peihl*

Figure 97. Sanborn Map of Site From 1884



Note: *From Historical & Cultural Society of Clay County, Received from Archivist Mark Peihl*

Figure 98. Sanborn Map of Site From 1954



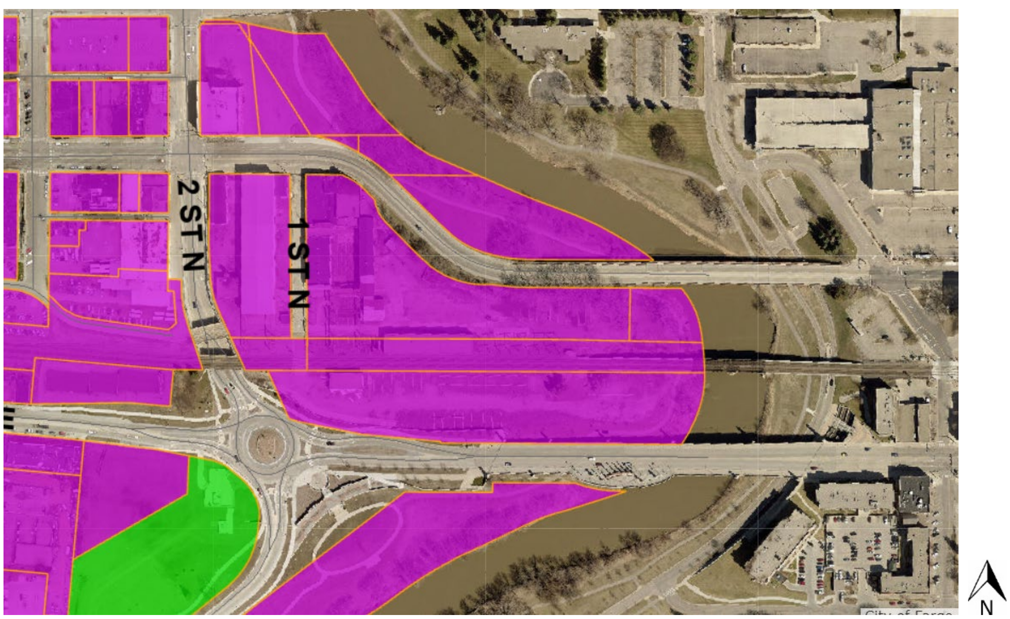
Note: *From Library of Congress (https://www.loc.gov/resource/g4174fm.g065361958/?sp=29&st=image&r=0.232,0.834,0.676,0.313,0)*

Zoning

The site is zoned as Downtown Mixed-Use (DMU). According to The City of Fargo's code of ordinances:

> The DMU, Downtown Mixed-Use District is intended to preserve and enhance the City's downtown area. The district allows a broad range of uses in order to enhance downtown Fargo's role as a commercial, cultural, governmental and residential center. In recognition of existing public facility capacity and downtown planning goals, very intensive development is allowed, with high building coverage, large buildings, and buildings placed close together. Development is intended to be pedestrian-oriented with a strong emphasis on a safe and attractive streetscape.

Figure 99. Site Zoning



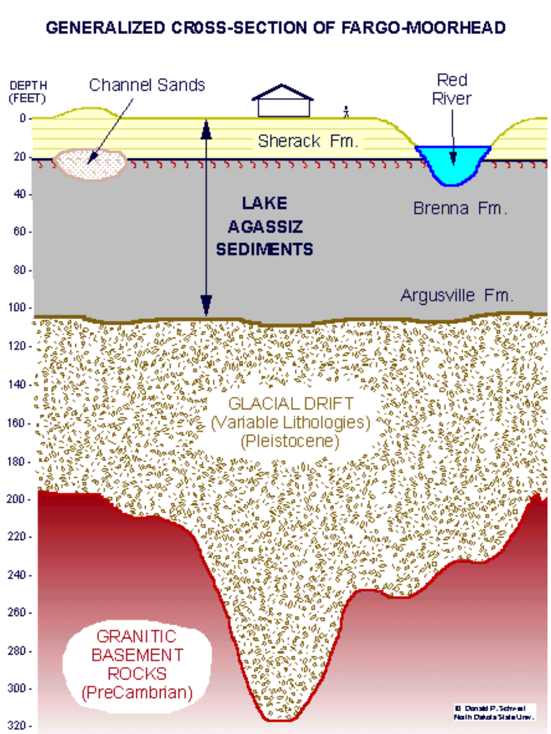
Note: *From The City of Fargo GIS (https://gis.cityoffargo.com/link/jsfe/index.aspx)*

Soil

The soil in the area is predominantly characterized by silty clay loam. This type of soil is known for its fine texture, combining sand, silt, and clay. Silty clay loam soils are adept at retaining moisture and have a higher capacity for nutrient retention, making them fertile and well-suited for various types of vegetation (Dept. of Geosciences NDSU, n.d.). However, they pose challenges in drainage and water management due to their tendency to retain water and become compacted. This calls for thoughtful construction and landscaping plans to ensure proper drainage and circumvent problems like waterlogging or foundation instability.

Additionally, the central basin of Lake Agassiz, covering parts of North Dakota and Minnesota, features clay-rich sediments with inherently weak properties. These clays are expansive and capable of absorbing large quantities of water, which in turn weakens them (Dept. of Geosciences NDSU, n.d.). While they can support low-load structures in Fargo such as houses and small businesses, they are unsuitable for larger-load structures like high-rises or bridge supports. For these heavier constructions, the load must be transmitted through the Lake Agassiz sediments to firmer materials more than 100 feet beneath the surface, typically glacial drifts like till, outwash, and other sediments from past ice ages (Dept. of Geosciences NDSU, n.d.).

Figure 100. Fargo Soil

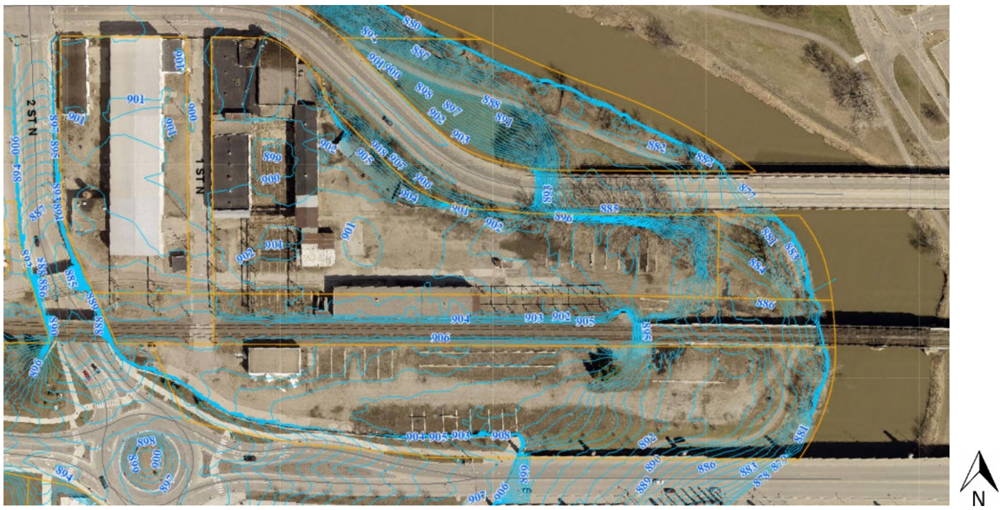


Note: *From ndsu.edu by Donald P. Schwert (https://www.ndsu.edu/fargo_geology/caissons.htm)*

Topology

The west side of the site is the higher end of the site and is relatively flat, while the east end closer to the river slopes downward towards the river.

Figure 101. Site Topology



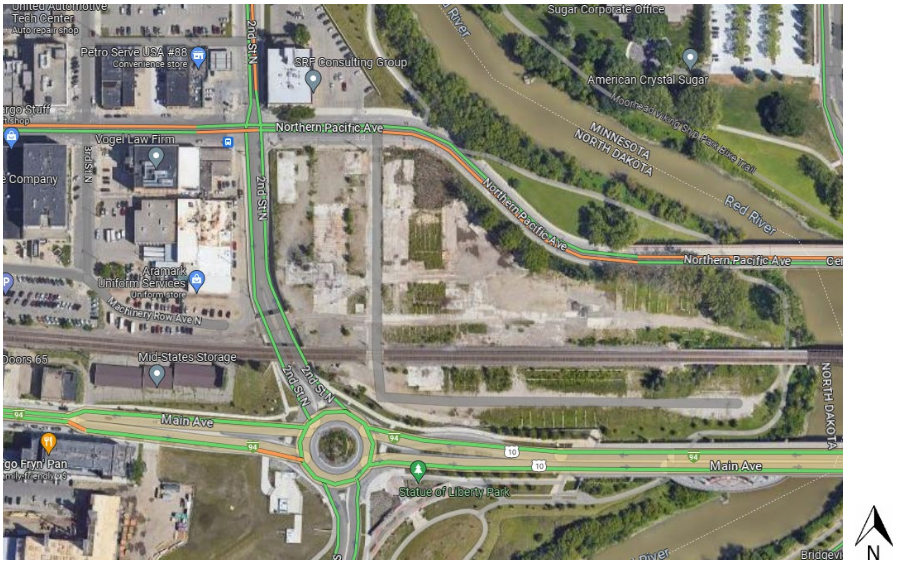
Note: *From The City of Fargo GIS (https://gis.cityoffargo.com/link/jsfe/index.aspx)*

Safety and Security

Figure 102. Peak High Traffic

Note: *Peak high in traffic is typically during weekdays during the day. From Google Maps (https://www.google.com/maps/@46.8744881,-96.7798936,17z/data=!5m1!1e1?entry=ttu)*

Figure 103. Peak Low Traffic



Note: *Peak low in traffic is typically during weekends during the night. From Google Maps (https://www.google.com/maps/@46.8744881,-96.7798936,17z/data=!5m1!1e1?entry=ttu)*

Site Visit

First Visit. On September 1st, 2023, I conducted my first site visit. The site presented a picture of urban neglect; overgrown weeds dominated the landscape, punctuated by remnants of torn-up concrete foundations and scattered metal scrap pieces. Evidence of past occupation was marked by graffiti along the retaining wall at the northern end and makeshift shelters, indicative of temporary homeless encampments, though none were present during my visit. Litter was a significant issue, with trash strewn across various areas of the site. The auditory backdrop was primarily the sound of traffic, particularly noticeable from the intersection of 2nd Street N and N.P. Avenue near the northwest corner. Four train tracks cross the site, with two active tracks running east to west, bisecting the landscape, and two neglected, inactive tracks. Amidst this urban decay, a natural resilience was observed: numerous butterflies flitted among the wild plants breaking through the concrete. On the lower east side, a serene contrast was provided by a park walking path, offering a tranquil boundary between the site and the adjacent river.

Figure 104. Visit 1 Image Location Map

Note: *1.1 = Visit 1 Image 1, 1.2 = Visit 1 Image 2, etc. (Modeled from Google Earth Pro, 2022 and Photoshop)*

Figure 105. Site Visit 1 Image 1

Note: *(Photo by Mason Groth, 2023)*

Figure 106. Site Visit 1 Image 2

Note: *(Photo by Mason Groth, 2023)*

Figure 107. Site Visit 1 Image 3

Note: *(Photo by Mason Groth, 2023)*

Figure 108. Visit 1 Image 4

Note: *(Photo by Mason Groth, 2023)*

Second Visit. On December 8th, 2023, my second visit to the site revealed a starkly different scene compared to my initial visit. With the onset of winter, the once overgrown vegetation had lost its vibrancy, casting a somber mood over the area. The diminished vegetation exposed more of the site, revealing an increase in trash accumulation. During my visit, a train passed on the active tracks, its presence momentarily dominating the soundscape with the loud dinging of the crossing arms. A subtle, smog-like odor from the nearby Aramark factory to the west drifted into the area, although not overpowering. Intriguingly, I observed an Aramark delivery truck utilizing the bridge over the inactive train tracks and entering the site to turn around. A new observation was the presence of a different homeless shelter closer to the river, alongside a homeless individual crossing the site, highlighting the ongoing human presence in this urban space. In contrast to my first visit, no wildlife was observed, emphasizing the site's seasonal transformation and its impact on the local ecosystem.

Figure 109. Visit 2 Image Location Map

Note: *2.1 = Visit 2 Image 1, 2.2 = Visit 2 Image 2, etc. (Modeled from Google Earth Pro, 2022 and Photoshop)*

Figure 110. Visit 2 Image 1

Note: *(Photo by Mason Groth, 2023)*

Figure 111. Visit 2 Image 2

Note: *(Photo by Mason Groth, 2023)*

Figure 112. Visit 2 Image 3

Note: *(Photo by Mason Groth, 2023)*

Figure 113. Visit 2 Image 4

Note: *(Photo by Mason Groth, 2023)*

Figure 114. Visit 2 Image 5

Note: *(Photo by Mason Groth, 2023)*

Figure 115. Visit 2 Image 6

Note: *(Photo by Mason Groth, 2023)*

Figure 116. Visit 2 Image 7

Note: *(Photo by Mason Groth, 2023)*

Figure 117. Visit 2 Image 8

Note: *(Photo by Mason Groth, 2023)*

Figure 118. Visit 2 Image 9

Note: *(Photo by Mason Groth, 2023)*

Detailed Space Program

Table 16. Detailed Space Program

Visitor Service	
Lobby and Entrance	2,000
Information and admissions	100
Visitor service office	320
Store/Gift Shop	1,420
Sales area	1,000
Managers office	120
Workroom	150
Storage	150
Support spaces	1,650
Coat rack	900
Vending machines	50
Restrooms	600
Unisex toilet	50
Nursing area	50
Visitor Service Total	**5,490**

Offices	
Exhibits office	860
Exhibits director	120
Developer/evaluator	240
Technician	120
Clerical	80
Workroom	300
Program offices	840
Program director	120
Educators	160
Project coordinators	160
Clerical	80
Visitors service manager	80
Volunteers	240
Development offices	1,220
Director	120
Development associate	240
Marketing manager	120
Marketing associate	160
Clerical	300
Workroom	280
Administrative offices	500
Finance and administative director	120
Accounting	120
Human Resources	120
Clerical	140
Executive offices	500
Executive director	180
Executive assistant	80
Vice president of programs	120
Vice president of administration	120
Office support spaces	1,780
Conference room	800
Library	150
Reception and waiting	220
Kitchen, toilets, mail, storage	610
Office total	**5,700**

Exhibits	
Exhibits	24,000
Large exhibit halls	5,000
Smaller exhibit halls	2,000-3,000
Exhibit support	320
Unisex toilets	160
Housekeeping and storage	160
Exhibits Total	**24,320**

Event space	
Event space	2,500
Storage	400
Kitchen	400
kitchen storage	120
Event Space Total	**3,420**

Exhibit Fabrication	
Wood shop	3,000
Metal Shop	400
Finishing room	1,000
Shop room	1,000
Office and toilet	170
Exhibit Fabrication total	**5,570**

Building Operations	
Shipping, loading dock, receiving, trash disposal	3,000
General storage	500
Fire and security control	80
Maintenance shop and janitor rooms	360
Building Operations Total	**3,940**

Animal Care and Maintenance	
Veterinary care	1,000
Food storage and preparation	1,000
Habitat maintenance and storage	1,000
Animal Care and Maintenance Total	**3,000**

Circulation space	**2,500**

Total Square Footage	**53,940**

Note: *(Table modeled after averages of space programs from a multitude of case studies and reference from spatial studies done in Building Type Basics for Museums by Arthur Rosenblatt)*

RESULTS AND CONCLUSIONS

Final Project Description

This thesis proposes the development of an Urban Science Center in downtown Fargo, North Dakota, uniquely situated on a regenerated brownfield site and architecturally inspired by biophilic design principles. The design aims to establish a deep connection with the natural world, particularly the Red River Valley, integrating sustainable practices with the local ecosystem. As a primary focus, the center will concentrate on exploring the ecological and geographical significance of the Red River Valley through interactive exhibits and educational programs centered on the region's biodiversity, climate, and natural phenomena. This will be complemented by a strong emphasis on STEM education, offering cutting-edge facilities and hands-on experiences in science, technology, engineering, and mathematics, designed to inspire innovation and curiosity among visitors.

In addition to its scientific and environmental focus, the center will also present sections dedicated to the history and culture of the Fargo area, ensuring a comprehensive cultural narrative. This multifaceted approach aims to make the Science Center a key cultural and educational landmark in Fargo, enhancing the understanding of the region's heritage while nurturing curiosity in science. Its strategic location and innovative design are poised to contribute significantly to the economic growth and urban revitalization of the downtown Fargo/Moorhead area. By attracting a diverse range of visitors, educators, and researchers, the center is expected to stimulate local businesses, enhance Fargo's cultural identity, and serve as a model for sustainable urban development and community engagement.

Project Objectives

- Create an immersive space that incorporates biophilic design principles to enhance the visitor experience
- Regenerate an abandoned brownfield site while connecting to the surrounding environment

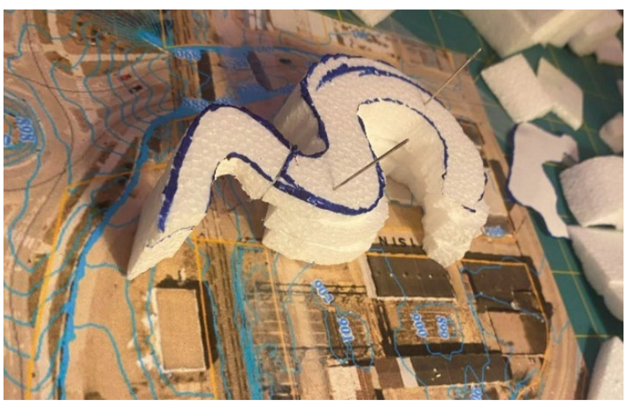
Project Design and Documentation

Process Models and Sketches

Figure 119. Mass Model Concept 1

Note: *This mass model idea was based on a box mass that would have dynamic forms extruding off of the sides of the box.*

Figure 120. Mass Model Concept 2

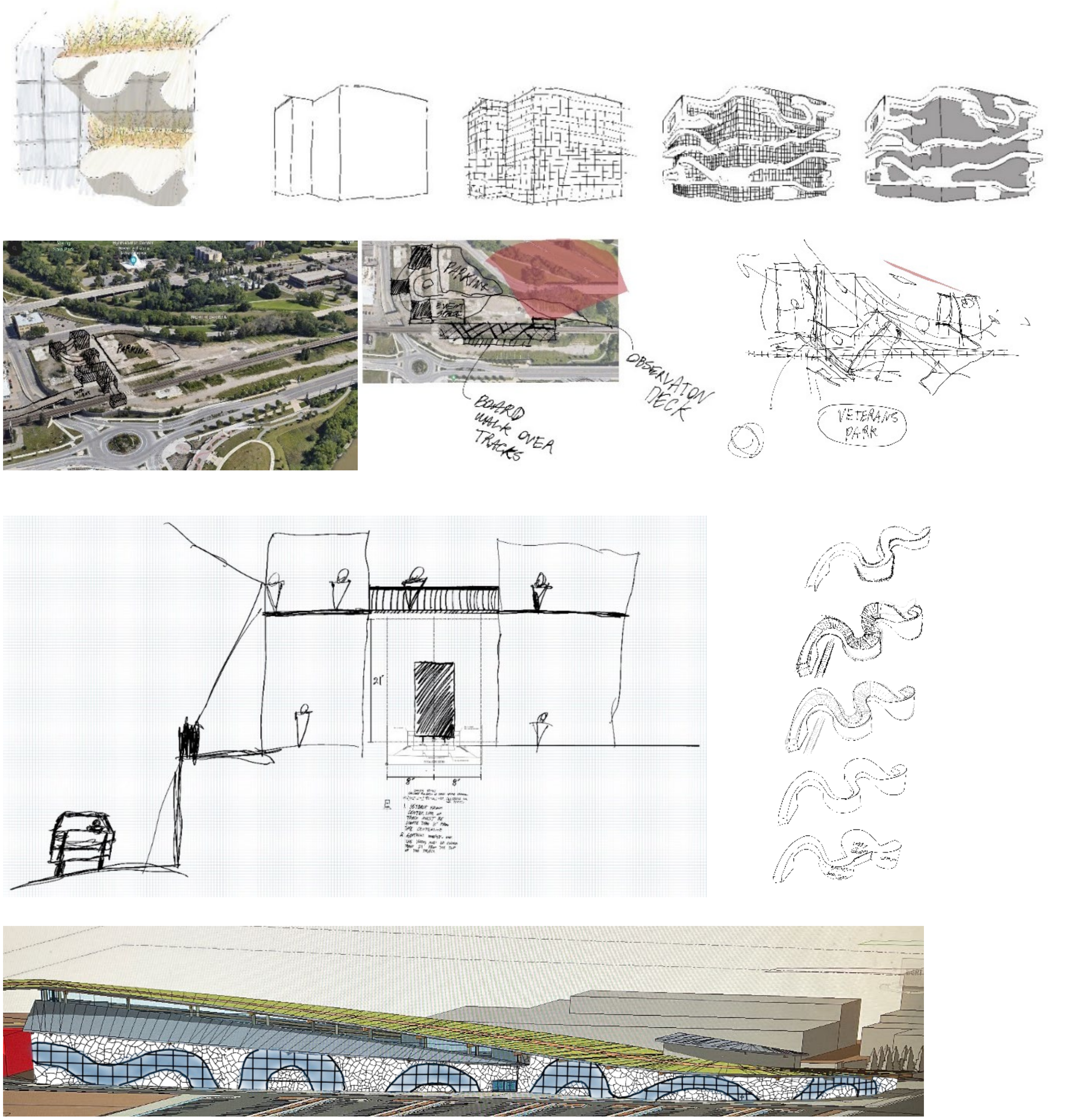


Note: *This mass model mimicked the meandering form of a river while connecting the other half of the site by crossing over the train tracks.*

Figure 121. Mass Model Concept 3

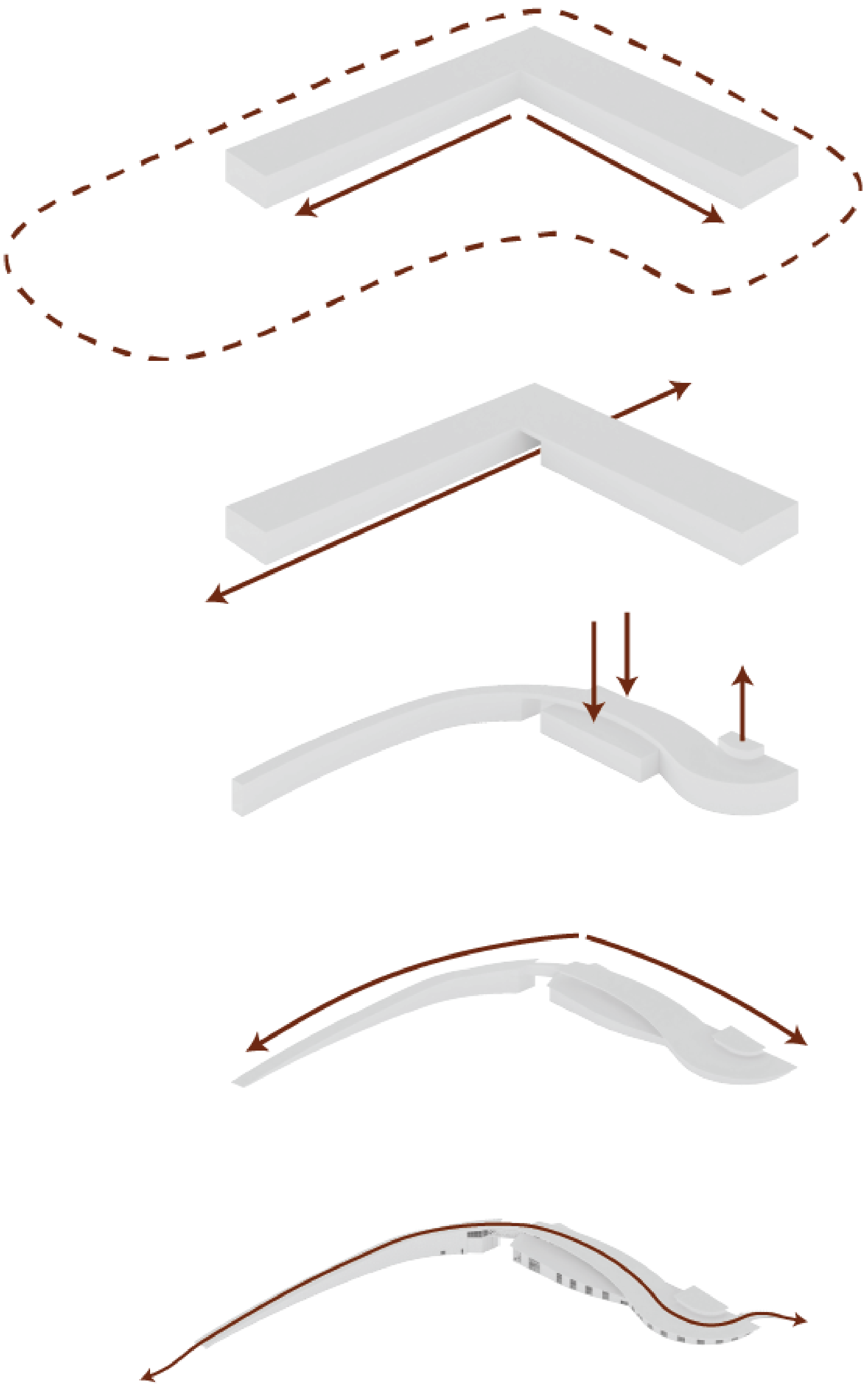
Note: *This mass model simplified the 2nd mass model's form by creating wider curves and incorporating both ends of the building to be lowered with the middle being the highest point. This form was the form that inspired the final form.*

Figure 122. Collage of Sketches Throughout Design Process



Note: *These are sketches from multiple different stages of the design process, some earlier on and some later in the process. (Some sketches were traced over images modeled after Google Earth Pro, 2022)*

Figure 123. Design Phases



Note: *Phase 1: An elongated form spans along the southwest corner, fitting into the site's lengthy curved shape. Phase 2: A cut through the mass to account for the train tracks splitting the site into two. Phase 3: Defining shape with pushing and pulling of heights. Phase 4: Sloping of roofs and creating a walkway across the main green roof to connect the two halves of the site. Phase 5: Cut out of openings and connection to existing paths.*

Final Design

Figure 124. Front Entry

Note: *The Red River Valley Science Center is designed to be more than just a building—it's a gateway to exploring and understanding the natural world around us. The architecture features heavy timber beams and columns, along with other natural materials, which evoke a strong connection to nature and provide visitors with a sense of authenticity and grounding. Large windows invite natural light to flood the interiors, creating a welcoming atmosphere that extends an open invitation to all who visit. This center is not just a place to learn; it's a place to experience, interact, and connect with nature through thoughtful design and innovative exhibits that celebrate and preserve our local environment. The facade of the building draws its inspiration from the natural elements specific to this region. It features metal paneling designed to mimic the appearance of dried, cracked mud, a frequent sight in the flood plains of the Red River Valley. This design choice is a nod to the dynamic nature of our environment, symbolizing the adaptability and resilience required to thrive in such a landscape. It's a visual connection that ties the building back to the very phenomena it aims to educate about, making it a landmark that is both functional and deeply symbolic.*

Figure 125. Site Plan

Note: *Due to river setbacks the main building is located on the west side of the site. This creates space for a nature park system that extends east, linking up with existing trails along the riverbank. This nature park features a main path that mirrors the meandering form of the Red River, with smaller side trails for more intimate explorations of the area. Throughout the park, there are various rest points where visitors can pause to enjoy the surroundings. The site design incorporates open prairie spaces and wildflower gardens among the trees, offering a diverse and engaging experience as one moves through the trail system.*

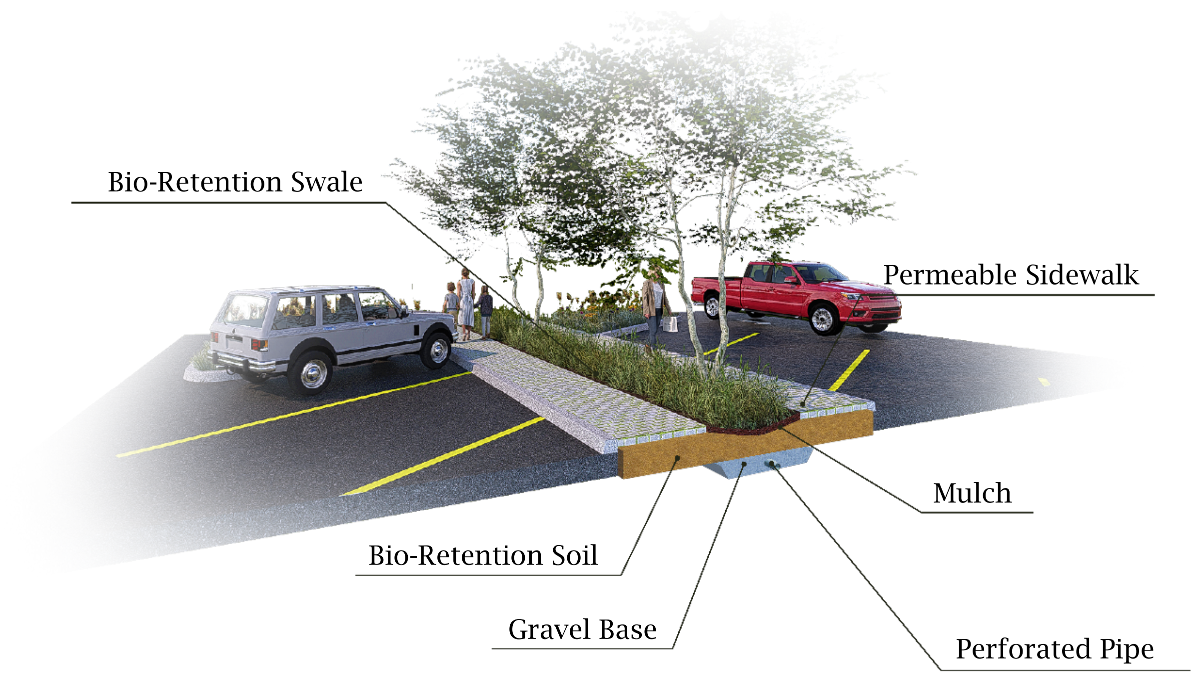
Figure 126. Park Prairie

Note: *This is a closer look at one of the open prairies within the park. It's designed as an interactive learning environment where nature classes from the Science Center can venture outdoors. Beyond educational purposes, this space invites the broader community to explore, relax, and connect with nature. Whether for leisurely walks, community gatherings, or personal reflection, the nature park serves as a valuable green space for everyone in the community to enjoy and appreciate the natural surroundings.*

Figure 127. Orthographic View

Note: *The connection to the existing paths and connection of the two halves of the site was one of the main site design goals. With this goal in mind, the entire roof was designed to be a walkable green roof system that allows visitors to go from one end of the site all the way across without needing to walk across the tracks or wait for trains. The green roof is not just a pathway; it's an extension of the natural landscape, featuring a variety of wild grasses native to the Red River Valley region. This design not only enhances the aesthetic and experiential qualities of the building but also supports local biodiversity and minimizes its heat island effect. Additionally, in areas where hard surfaces are unavoidable, such as the parking lot, bio-retention swales have been integrated between parking rows. These swales manage runoff water and filter out pollutants, effectively helping to remediate the site's soil while maintaining functionality and environmental responsibility.*

Figure 128. Bio-Retention Swale Section Cut



Note: *These swales facilitate the filtration and recharge of groundwater, while also remedying the contamination left by the historical industrial use of the site.*

Figure 129. Green Roof Walkway

Note: *A view of the green roof walkway system.*

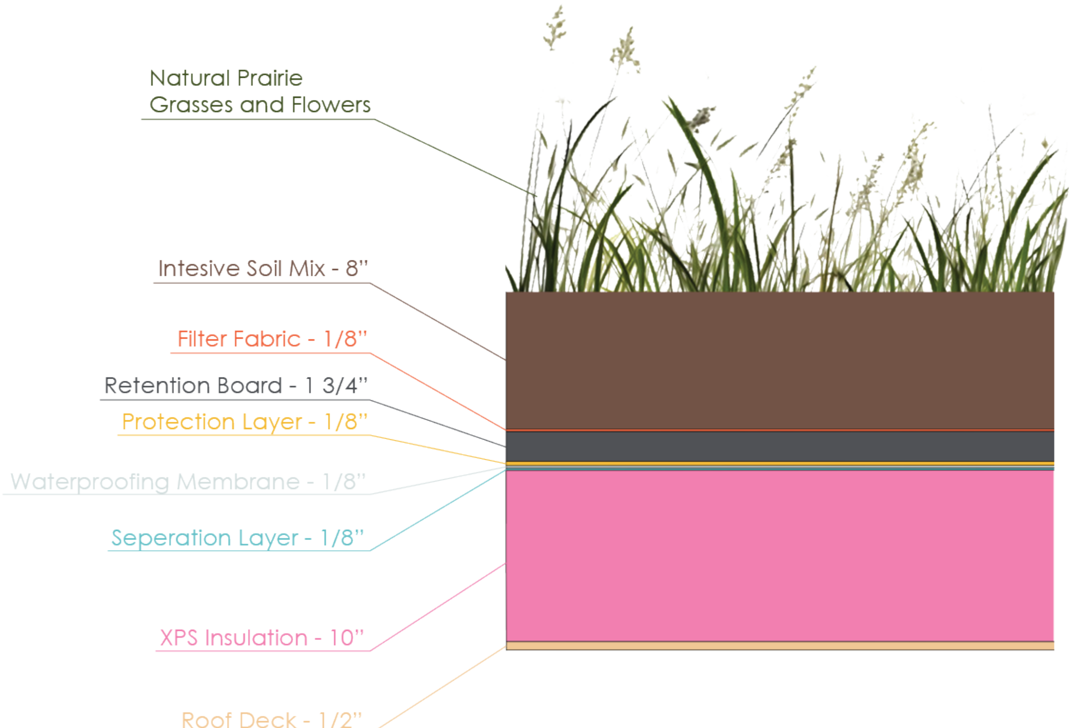
Figure 130. Green Roof Lookout

Note: *A view from the green roof lookout spot.*

Figure 131. 3D Section Cut

Note: *A section cut view that showcases the integration of the green roof and highlights the natural materials and color tones used throughout the Science Center, contributing to a warm and inviting atmosphere.*

Figure 132. Green Roof Section Cut

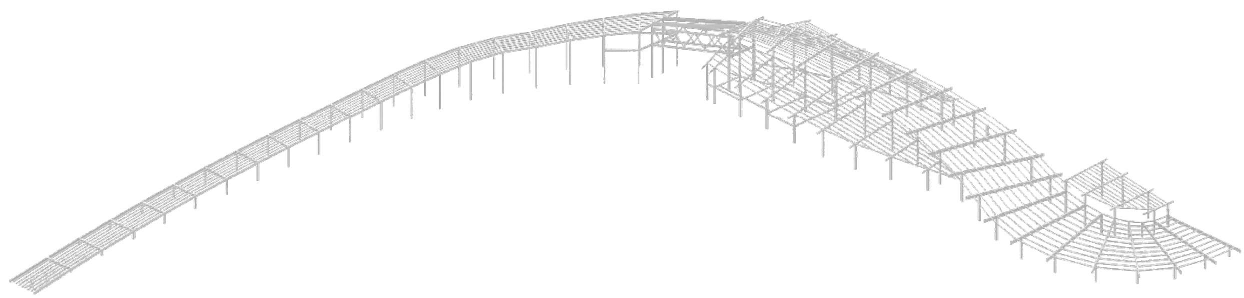


Note: *The green roof uses an intensive soil mix with a depth of eight inches, ideal for wild grasses and flowers.*

Figure 133. Skyway over Tracks

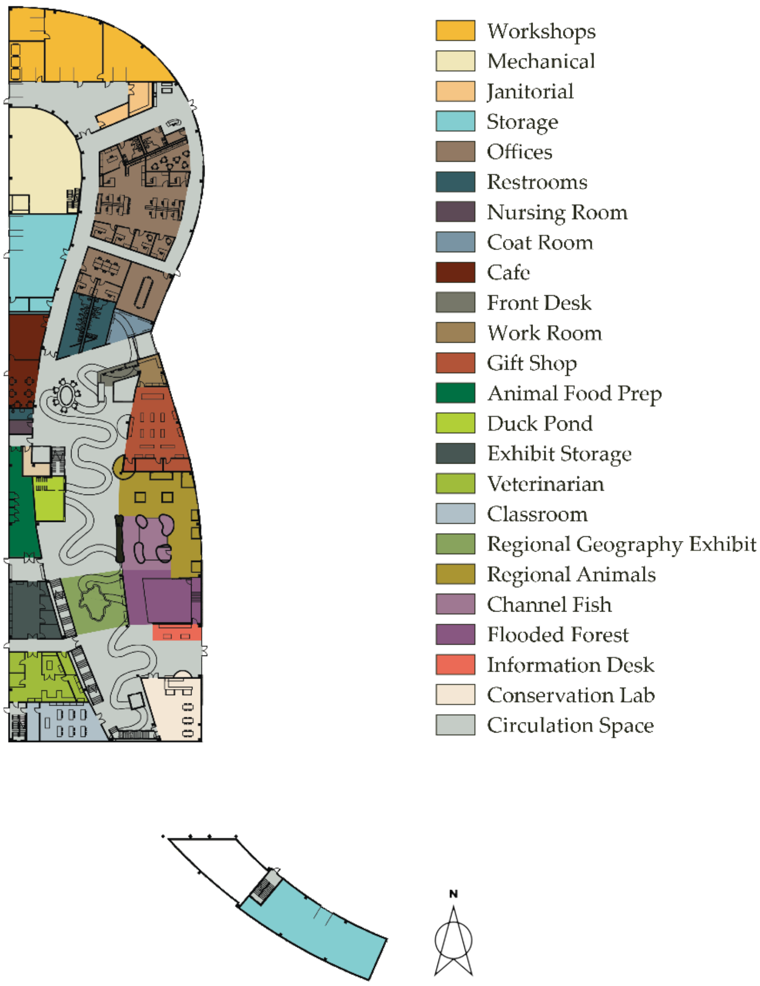
Note: *A view at the skyway bridge over the train tracks.*

Figure 134. Structural Diagram



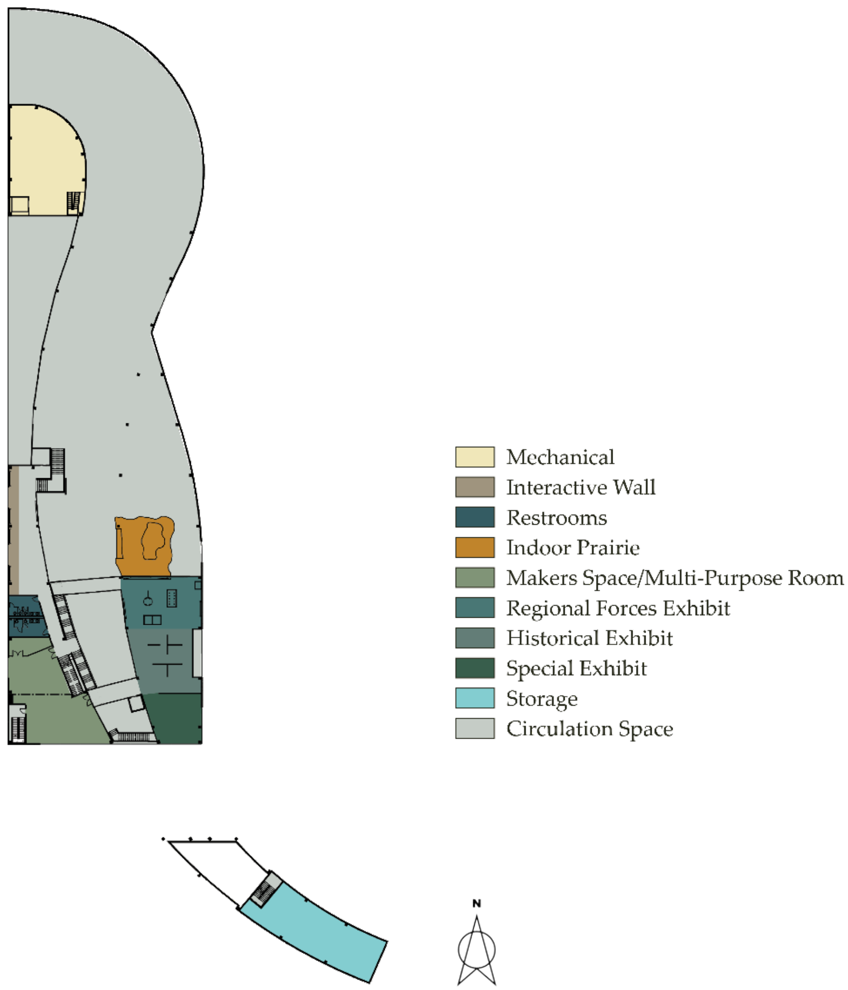
Note: *The Structure is made up of heavy timber columns and beams. The green roof grid follows the shape of the green roof and the side roofs follow a standard grid system. The columns are spaced 30 feet apart from each other. The long-spanning beams that hold the green roof up range from 10 feet long to 45 feet long from column to column.*

Figure 135. First Level Floor Plan



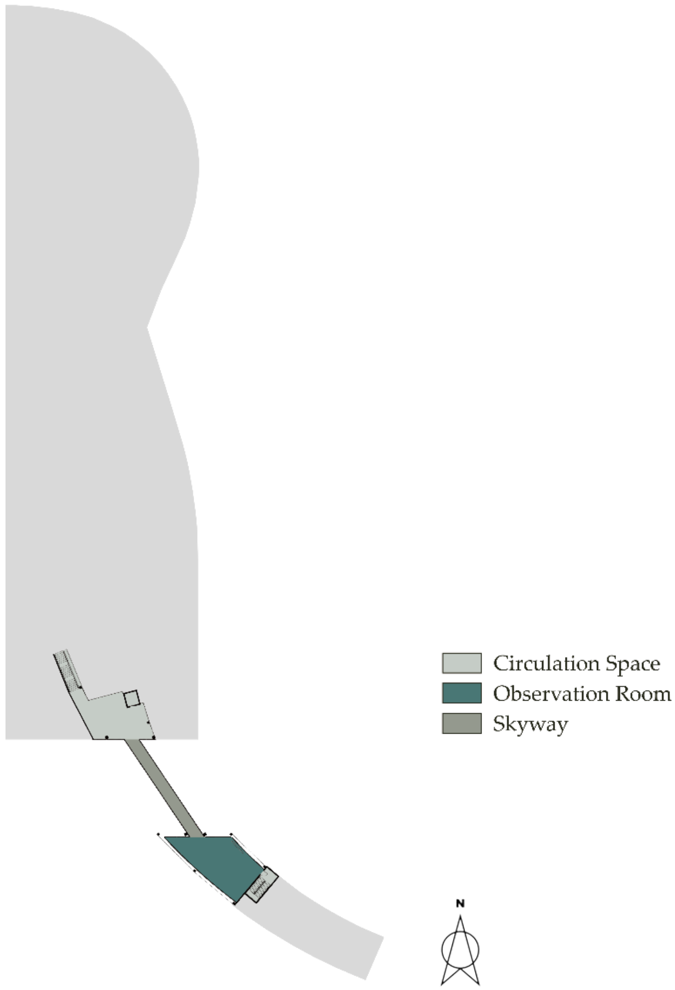
Note: *The building is split in two based on the function of the space. The north end of the building is dedicated to operational functions including office spaces, building operations, and workshops. As visitors enter through the centrally located main entrance, they are greeted by the front desk that is positioned to offer a clear view down the main hallway. Directly across from the entrance is the café, a convenient spot for visitors to grab some food or a drink during their stay. The main hallway itself is uniquely marked with a floor pattern that traces the actual form of the Red River, leading visitors through a journey of the first-floor exhibits located along the east side. These exhibits are designed to immerse visitors in the region's ecology, featuring a variety of animal exhibits, large fish tanks, a duck and turtle pond, and a flooded forest display. There's also a root wall that educates about the extensive root systems of local grasses and a map table that illustrates the topographical elevation changes from throughout the region. On the west side of the hallway, are essential support spaces that include an animal food prep kitchen, an exhibit storage area, and a veterinarian office. Along the southern wall is a large lecture classroom and the conservation lab. These spaces are pivotal for educational programs, such as summer camps and school field trips, allowing hands-on learning about conservation practices. Together, these elements create an engaging and educational environment that highlights local wildlife and ecological systems. The very southern tip of this floor plan shows a large storage garage that would house all of the gardening equipment and materials, for maintaining the park and other vegetation throughout the building.*

Figure 136. Second Level Floor Plan



Note: T*he second floor is primarily located on the southern side of the building, with an array of exhibits and spaces designed to expand the educational scope of the center. Here, visitors can explore a wide range of exhibits focused on natural forces and phenomena. Adjacent to this, there's an exhibit dedicated to local history, offering insights into the region's past and its development. Next to this, the special exhibit space features rotating displays that change periodically. These exhibits are often STEM-related and can vary widely in topics, these spaces are typically set up by outside vendors, providing fresh and exciting content that draws repeat visitors. On the southwest corner, a makers space doubles as a multipurpose room, capable of hosting events and supporting a variety of educational formats. One of the unique architectural features on this floor is the indoor prairie. This installation allows visitors to feel as though they are gazing across a prairie, regardless of the season. Strategically placed within this indoor prairie is a cutout above the catfish and paddlefish tank, giving the impression of looking down into a natural pond.*

Figure 137. Third Level Floor Plan



Note: *The third floor houses the skyway that brings guests over the train tracks and into the observation room. The observation room overlooks the nature park to the northeast and the busy roundabout on Main Street to the southwest.*

Figure 138. Main Entry

Note: *Throughout the main entry lobby there is a generous use of natural materials and vegetation that together create a warm and inviting entrance. Heavy timber beams and columns frame the structure, giving it a grounded, organic feel that harmonizes with the surrounding environment. Trees and grasses are thoughtfully integrated into the design, blurring the line between the indoors and outdoors and making the transition into the center a seamless experience that begins the moment you approach the building.*

Figure 139. Regional Exhibits

Note: *This view is from the main hallway facing the regional animal exhibits, featuring a variety of amphibians and fish native to the area. The design of this exhibit space includes a large, earth-like tunnel that visitors can walk through, symbolizing the earth's surface and the underwater burrows favored by catfish. It's an immersive experience designed to bring visitors closer to the natural habitats of these species. Alongside this, there is a root wall display that reveals the extensive length of roots beneath the ground—a vital, yet often unseen part of our ecosystem. Above the earthlike tunnel is the indoor prairie, a feature that extends the connection to nature to the second floor and throughout the building.*

Figure 140. Flooded Forest Exhibit

Note: *This view is from inside the earth-like tunnel, providing a view of the channel fish exhibit's backside, which is adjacent to the flooded forest display. The flooded forest exhibit simulates the annual springtime flooding experienced in local forests, creating an authentic visual and educational experience of this natural occurrence. To enhance the sensory experience, the floor here is covered with rubber flooring, adding a soft, squishy feel under your foot that mimics the forest floor during the flood season, making the exhibit not just a visual journey but a tactile one as well.*

Figure 141. Second Floor Walkway

Note: *From the second floor, the indoor prairie is visible. Below, you can observe the duck pond, which is home to various types of waterfowl native to the region. The Red River Valley serves as a vital habitat and migratory stopover for these species, and this exhibit showcases some of these birds, along with local turtles and fish.*

Figure 142. Third Floor Balcony

Note: *From the third level balcony, visitors are able to gaze over the main hallway and second floor exhibits.*

Conclusions

The architectural design for the Red River Valley Science Center accomplishes the project's goals of creating a space that not only educates but also deeply connects with visitors and the local community. The use of heavy timber beams and natural materials throughout the structure evokes a connection to the natural world, providing a tactile and visual experience that aligns with the center's focus on environmental education and sustainability.

The design of the facade, inspired by the region's natural dried mud patterns, and form of the building, celebrates local environmental characteristics and challenges, turning the building itself into a teaching tool that speaks to the area's flood-prone ecology. Inside, the layout and features of the exhibits allow visitors to experience and understand local wildlife and ecosystems in a context that mirrors their natural environments.

The green roof system serves a dual purpose by enhancing building insulation and reducing runoff, while also providing a unique recreational space that offers panoramic views of the surrounding area and direct interaction with native plant species. This design feature not only helps in controlling the building's climate but also plays a crucial role in educating the public about sustainable building practices and urban ecology.

Furthermore, the facility’s integration with existing park paths and its proximity to the Red River enables it to serve as a seamless extension of the community's public space. This encourages greater interaction between the center and the community, fostering ongoing educational opportunities outside of the traditional indoor environment. The design’s thoughtful inclusion of multipurpose spaces and the special exhibit areas ensures that the center can host a variety of events and adapt to changing educational needs, making it a versatile community resource.

In conclusion, the Red River Valley Science Center’s design successfully bridges the gap between architectural form and functional necessity, creating a space that is both a celebration of and a portal to the natural world. It stands as a testament to how thoughtful design can transform a brownfield site into a vibrant hub for education, community engagement, and environmental stewardship, making it a model for future projects aiming to revitalize and educate urban populations.

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